POWER PLANT ENGINEERING

Established Over 31 Years

VOL. XXXI CHICAGO, JUNE 1, 1927 No. 11

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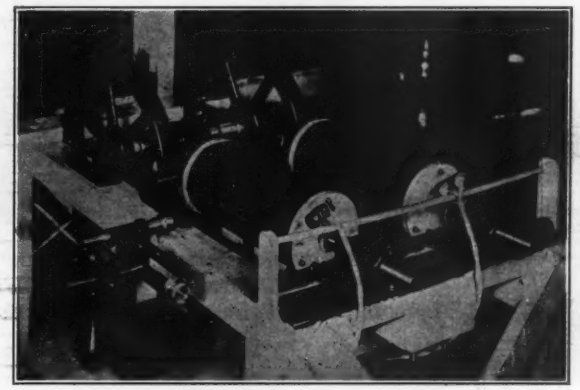

Back to the Nursery

Halfway down the stairs
Is a stair
Where I sit. . . .
It isn't up
And it isn't down
It isn't in the nursery
And it isn't in the town.

SOMEHOW WE FEEL that Christopher Robin did the diplomatic thing in avoiding the troublesome immediate decision of whether to go up or down and still he remained in a strategic position to go either way when it pleased him to do so.

Along with other modern tendencies steels, even the best of them, can no longer be judged by old standards when high temperatures are concerned. The old strength-temperature diagram has been replaced by "creep limit curves." Whether or not this term was adopted to indicate the infancy of a branch of metallurgy developed by the new high pressure era or for a more significant reason we shall leave each individual to judge after reading the article on page 639 dealing with the importance of the creep limit of metals on modern high-pressure plant design. A testing machine used in the laboratories of the Chapman Valve Mfg. Co. for pioneer work along this line is shown above.

In other words, it behooves us to choose a half way step so that we can jump either way and suit our design data to meet specific conditions whether in the nursery with the new creep limit or in the town with the old popular strength-temperature diagram.

Incidentally, pioneer experiences with high-pressure steam plant design at Edgar Station are told on page 605. As the first high-pressure commercial plant in the country, it pointed out the practical possibilities of high pressure and emphasizes the importance of proper metallurgical data.

New Bayside Station Aids Wisconsin Hydro Plants

PLANT IS DESIGNED WITH NO SPARES IN MAIN UNITS, WHICH CONSIST AT PRESENT OF TWO 10,000-KW. TURBINES BLED FOR FEED WATER HEATING AND TWO SINGLE-PASS BOILERS WITH AIR PREHEATERS AND WATER-COOLED FURNACES FIRED BY UNIT PULVERIZERS

RECENT DEVELOPMENTS in the power system of the Wisconsin Public Service Corp., serving a large territory in northern Wisconsin, have indicated the desirability of having a steam plant to operate in conjunction with the hydro-electric plants. To perform this service the corporation has recently completed a new steam power plant, known as the Bayside station, located on the shore of Green Bay, at the mouth of the Fox River about 2½ mi. north of the city of Green Bay, Wis.

This station, with an initial capacity of 20,000 kw. in two units, is designed to run steadily at full capacity in the winter months to take the added load imposed on the system at that time, which is also the time when the hydro plants have the least water. Land, condensing water and railroad facilities are suitable for the future development of this plant to a capacity of 100,000 kw., if the conditions of the system warrant it. The station was located at Green Bay because of the water and railroad facilities and also because that point is central with respect to the transmission system.

With the above considerations in mind, the plant was designed to operate for long periods without shutdown. No spare capacity in main units is provided. Two turbines and two boilers are installed, each boiler designed to supply steam to one turbine. Steam is bled from the turbines at three points for feed water heating. Boilers are of the single-pass type with a heater section, a steamer section and a superheater section; the furnaces are almost entirely water-cooled and are fired by unit pulverizers. Boilers are equipped with two different types of water-cooled walls and two different types of pulverizers to secure comparative operating characteristics. Each boiler has an integral heater section which is designed to perform the same function as is performed by a separate economizer with various other types of boiler but which at the same time forms part of the heating surface of the boiler. Use of extraction feed water heating and the advantages of using preheated air with the pulverized fuel furnaces led to the use of air preheaters also. These are of the rotary element type with integral forced and induced draft fans.

Selection of water-cooled walls for these furnaces was based on the necessity for continuous operation of boilers over long periods with no shutdown on account of refractory trouble. Since there is very little refractory in the furnace walls, and since evaporated water is used in the boilers, this assumption of continued service seemed reasonable. Unit pulverizers were selected because it was felt that they could be operated for the same long periods as the walls without the necessity of shutting the boiler down for repairs, since most of the repairs to the pulverized coal equipment can be made while the furnace is in service. In short, the boiler equipment was designed with the thought that it would be shut down only during the period of the annual overhaul.

Figure 3 shows the general relation of the station to the surrounding territory. It is built on the left bank of the Fox River just where the river empties into Green Bay. Condensing water is taken from the main ship channel through a dredged channel from a point north or downstream from the plant about 1300 ft. and is discharged upstream from the station. As the river is to some extent contaminated by the paper mills farther up and as the channel bears to the east at this point, it was felt that colder and purer water would be obtained in this way with less chance of condensers being fouled.

For the present, all coal will be brought to the plant by rail, although later, if the amount of coal warrants, it will be obtained by water. A large storage space has been provided near the railroad track capable of storing 50,000 t.

In the Bayside station the principal feature of in-

terest to the mechanical engineer is the boiler room, since the incorporation of the equipment noted above leads to an unusual and extremely simple layout. The boiler room contains two single-pass boilers, each supplied with pulverized coal by two unit pulverizers and discharging its flue gas through two air preheaters. The main open feed water heater, evaporators and evaporator condenser and high heat level bleeder heater are also installed in the boiler room. It contains, therefore, two boilers, four unit pulverizers, four air preheaters, evaporators and water heaters, the necessary piping and control boards and nothing more. This general arrangement is shown in cross-section in Fig. 2.

In the side walls of both furnaces, the water tubes extend only to the top of the ash hopper, the hopper being of refractory construction with an ash gate at the bottom. No part of these walls or of the refractory burner walls admits air to the furnace, since it all comes in at the burners, as will be explained.

Another interesting feature of this setting is the automatic soot blower installation furnished with this boiler. Stationary soot blower elements are placed between each two rows of tubes. These elements are operated automatically in the proper sequence by electric motor, the operation being started simply by pushing a button on the control board. A system of small light signals indicates the operation of the various blower elements.

Two different types of unit pulverizers and burners are used. Coal is taken direct from the overhead bunker to the pulverizers without drying, as shown in Fig. 2. A portion of the air from the preheaters, about 15 per cent, is fed through the mills with the coal and aids in drying the coal during pulverization. The temperature of this air will be between 275 and 350 deg. Pulverizers are motor-driven and each is designed to pulverize 4 t. of coal an hour, which is sufficient to carry the boiler at about ⅔ of its full capacity. The mills for No. 1 boiler have separate exhausters located on extension of the mill shaft, while those for No. 2 boiler have the exhauster incorporated as part of the mill. Feeders of both types of mills are driven separately; in one case by 1-hp., squirrel cage, ball-bearing motors; in the other by d.c. variable speed motors with rheostat control.

From the mills the mixture of pulverized coal and preheated air, which acts as primary air, is blown directly to the burners. These are of the recently developed turbulent types and of two different makes. Boiler No. 1 is fired by four of these burners in two pairs, one directly above the other, as shown in Fig. 10. Here the two upper burners have their inlet pipes brought together and connected to one pulverizer and

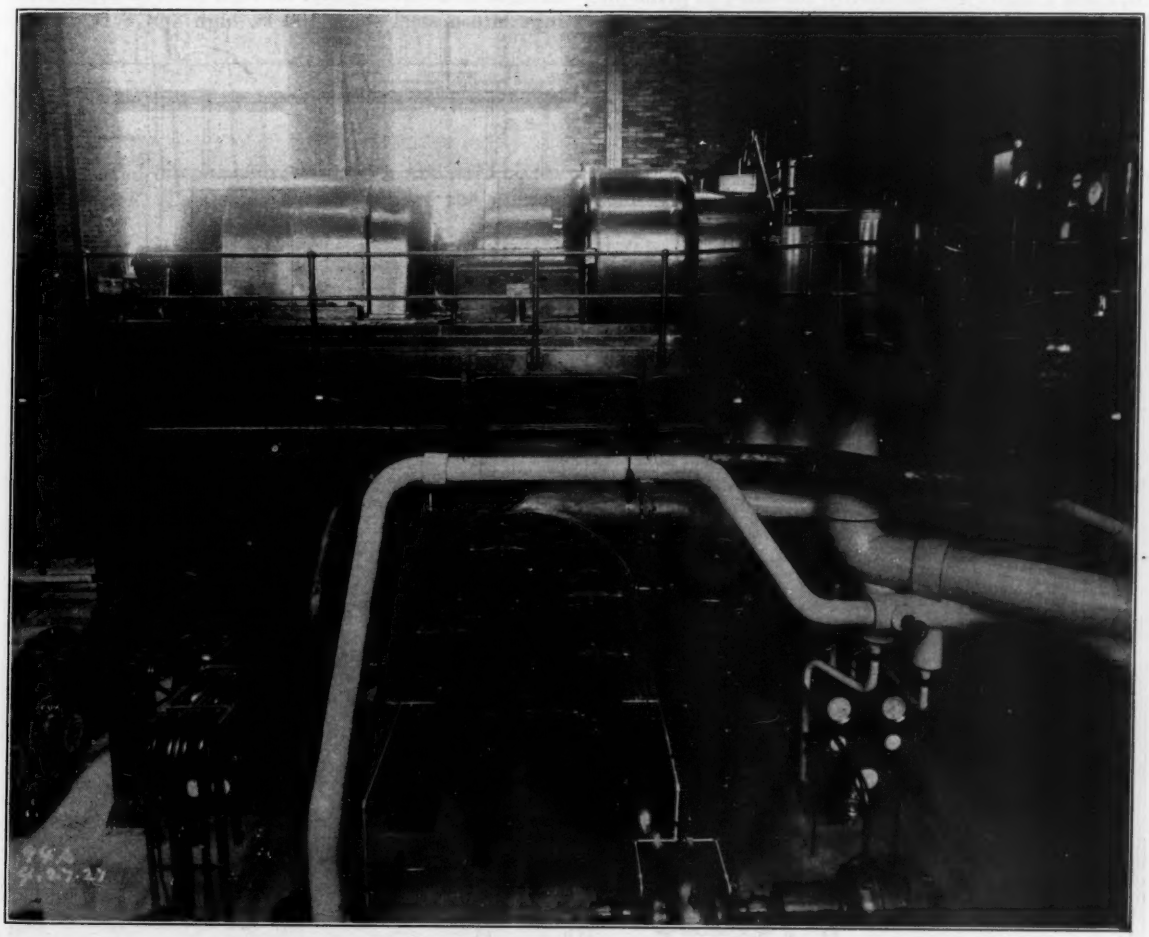

FIG. 1. ONE OF THE 10,000-KW. TURBO-GENERATORS, SET ON STRUCTURAL STEEL WITH CONDENSERS AND AUXILIARIES BELOW IT

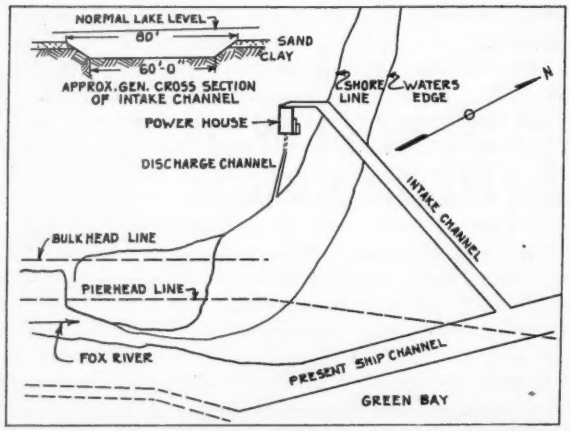

FIG. 3. PLAN OF STATION SITE, SHOWING HOW CONDENSING WATER IS TAKEN FROM DOWNSTREAM AND DISCHARGED UPSTREAM

the two lower burners connected to the other pulverizer. For Boiler No. 2 the four burners are set in a straight line across the furnace, as shown in Fig. 11, the first and third burners being supplied by one pulverizer mill and the second and fourth by the other.

Although differing somewhat in details of construction, these burners are essentially the same in principle. The pipe carrying the coal and primary air enters the burner where a cone at the exit spreads the stream. Surrounding this exit pipe and cone is a casing to which preheated air is led through suitable ducts. Vanes are located in such a way that the secondary air entering from the casing is swirled into the stream of coal and primary air, thus producing a turbulent action of the mixture and promoting complete combustion. In the No. 1 burners these vanes are crosswise of the outer casing, as shown, near the nozzle. In the No. 2 burners the cone is provided with spiral vanes which also project into the secondary air space. These vanes impart a swirling motion to the secondary air as well as to the stream of coal and primary air. The object of this design is to maintain the swirling motion when operating at low loads, at which time the pressure in the preheated air boxes around the burners may be low on account of the lower speed of the forced draft fans.

Each boiler is served by two rotary-element type air preheaters designed to heat 220,000 lb. of air per hour from room temperature to 340 deg. with gases entering at 480 deg., these figures being for the peak load conditions. These preheaters are mounted directly over the boilers, as shown in Figs. 2 and 5. Each preheater includes a forced draft and an induced draft fan and these, together with the rotating element of the preheater, are driven from one motor. Flue gas is discharged at about 250 deg. through short external breechings into a steel stack 100 ft. high and 8 ft. in diam-

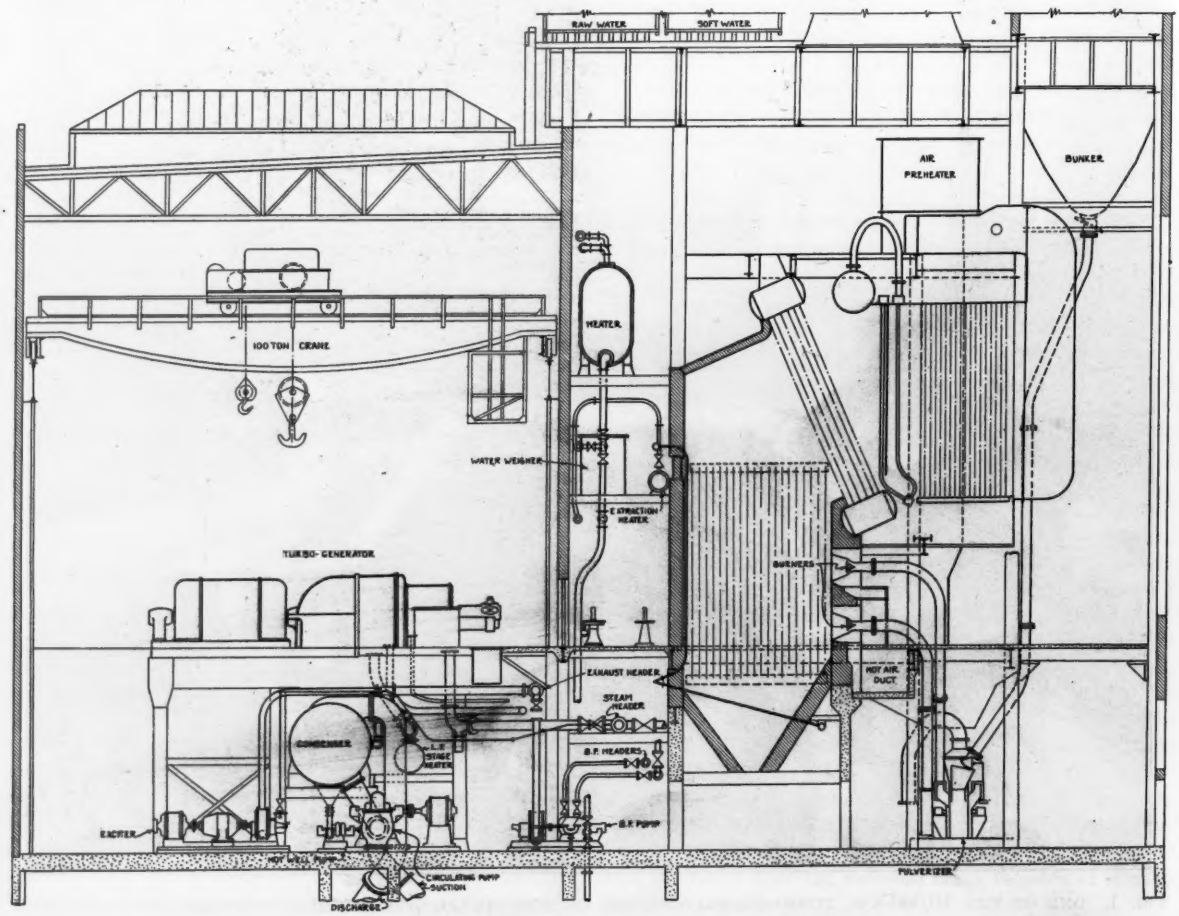

FIG. 2. THIS CROSS-SECTION SHOWS THE SIMPLICITY OF THE LAYOUT IN BOTH BOILER AND TURBINE ROOMS

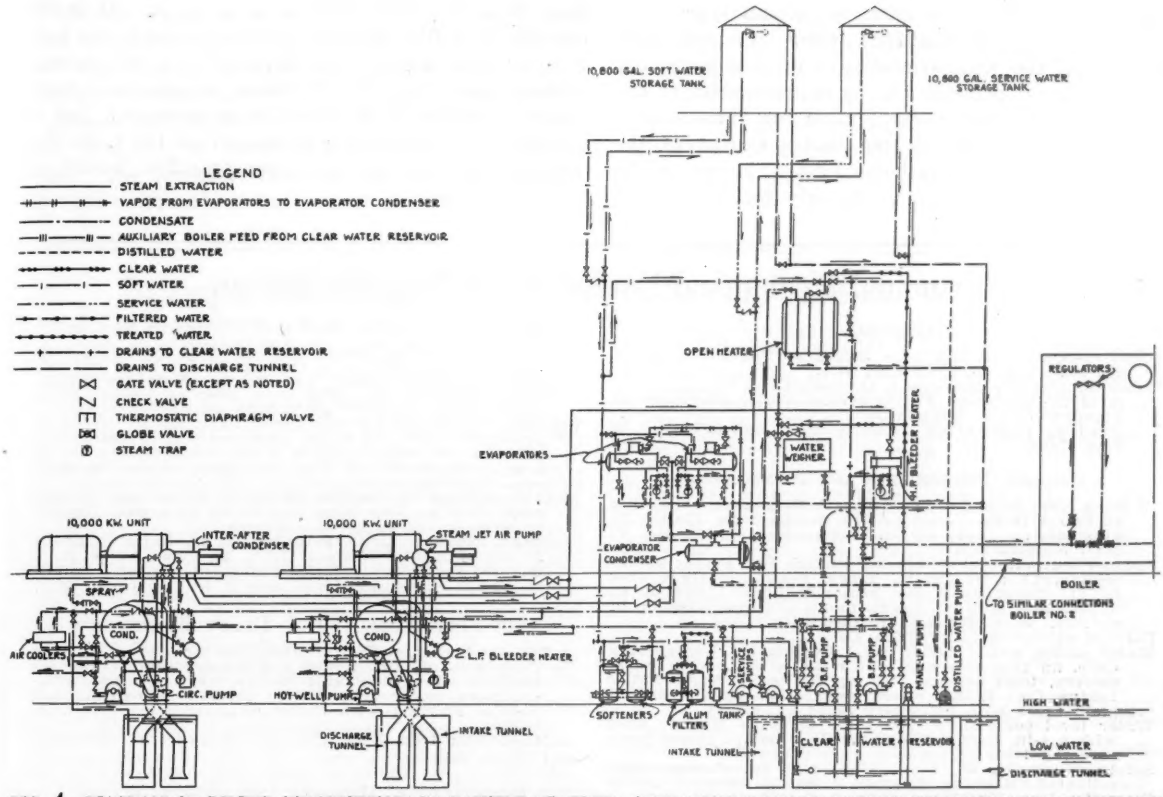

FIG. 4. DIAGRAM OF PIPING CONNECTIONS IN BAYSIDE STATION; OPERATION OF GANG VALVES ON GENERATOR AIR-COOLER IS SHOWN HERE

eter, supported on plate girders, which are part of the roof structure. This stack serves both of the present boilers.

An interesting arrangement of a feed water level regulator and a constant excess pressure regulator is used in the feeding of these boilers. A constant excess

FIG. 5. EACH BOILER IS EQUIPPED WITH TWO ROTARY-ELEMENT TYPE AIR PREHEATERS WITH INTEGRAL FORCED AND INDUCED DRAFT FANS

pressure regulator of the mercury column type is installed just ahead of the feed water level regulator. The object of this arrangement is to provide for a constant differential pressure on the opposite sides of the water level controller to compensate for variations in resistance to flow through the heater section of the boiler due to variations in boiler load. This makes the water level regulator responsible only for the control of the water level and it does this better than when it also has to take care of pressure fluctuations.

Most of the coal is received direct from docks in Green Bay and, after being weighed in the cars on track scales, is unloaded directly into the receiving hopper which feeds it to an apron conveyor with a magnetic separator at its head. This separator is charged by a 5.75-kw. motor-generator set. The apron conveyor loads a 36-in. belt conveyor having a capacity of 70 t. of lump coal an hour; this feeds to a ring crusher of 100 t. an hour capacity, which crushes it to ¾ in. It is then elevated by a 70-t. an hour bucket elevator to the boiler room bunkers, where it is distributed by a belt conveyor with automatic tripper. Provision is made for a second bucket conveyor to be added when necessary, but the present belt conveyor has a capacity of 150 t. an hour, which would take the coal from two 70-t. bucket elevators.

All of this coal conveying equipment is driven by ball-bearing motors with interlocks to insure starting and stopping in proper sequence. A small automatic sampler crusher is provided to aid in making up samples of the coal as it is weighed in. No weighing equipment is installed in the boiler room; coal weights are taken from the track scales and also by calibrating the speed of the feeders on the pulverizing mills. Ash collecting in the hoppers of the furnaces is dumped direct into industrial cars.

Principal Mechanical Equipment in Bayside Station

General

Location—On Green Bay near mouth of Fox River, about 2½ mi. north of Green Bay, Wis.
Capacity, present—25,000-kv.a. in 2 units.
Operated by Wisconsin Public Service Corp., subsidiary of Standard Gas & Electric Co.
Designed by engineering department of Byllesby Eng. & Man. Corp.

Boilers, Pulverizers and Auxiliaries

2 Edge Moor Iron Co. single pass boilers, each consisting of two 1310-hp. 5-unit boilers, designed for 130,000 lb. of steam an hour; 350 lb. steam pressure, 700 deg. F. total temperature.
Steamer section: 5 units heating surface 5620 sq. ft.; heater section, 15 rows 3¾-in. tubes, heating surface 7390 sq. ft. Total steam and heater sections, 13,010 sq. ft. Superheater section: 5 sections 1½-in. tubes, 4100 sq. ft. surface. Soot blowers furnished with boiler.
Furnace arches—M. H. Detrick Co.
Water cooled walls: boiler No. 1 Combustion Engineering Corp. fin tube side and rear walls with Lopulco water screens, total surface 1705 sq. ft.; boiler No. 2 Fuller Lehigh Co. Bailey water walls, 1214 sq. ft. surface, plain tubes with refractory faced c.i. blocks.
Water level controllers—The Stets Co. type B, cast steel with a 4-in. Mercon Regulator Co. constant excess pressure regulator across each Stets controller.
Safety valves, 3½ in., 6 on boiler, 2 on superheater—Consolidated (Manning, Maxwell & Moore, Inc.).
Blowoff valves—The Edward Valve & Mfg. Co.
Water columns with high and low water alarm—Edge Moor Iron Co.
Water column illuminators—National Co., Boston, Mass.
Soot blowers, automatic, Edge Moor Iron Co.

Pulverized Fuel-Burning Equipment

BOILER NO. 1

2 Combustion Engineering Corp. No. 7 Imp. pulverizer mills, driven by 75-hp., 1200-r.p.m. Westinghouse squirrel-cage, constant speed motors with Fairbanks-Morse 1-hp. ball bearing motors on feeds.
2 Combustion Engineering Corp. No. 9 exhausters, driven by 20-hp. Fairbanks-Morse motors.
4 Combustion Engineering Corp. Couch burners; air pressure at burners 2 in.; maximum temperature of air at mill, 275 deg.

BOILER NO. 2

2 Furnace Engineering Co. Simplex type 5A unit pulverizers, driven by 75-hp., 1200-r.p.m. Westinghouse squirrel-cage, constant speed motors, with 1-hp. ball bearing Fairbanks-Morse motors on feeders.
4 Furnace Engineering Co. Simplex type D burners. Air pressure at burner 1½ in.; maximum temperature of air at mill, 300 deg.

Coal and Ash Handling Equipment

1 American Pulverizer Co. ring crusher, 550-r.p.m., 100 t. an hour to ¾-in. size, driven by 50-hp. Fairbanks-Morse motor.
1 Sturtevant Mill Co. No. 00 automatic coal sample crusher, driven by 2-hp., 220-v. motor.
2 Western Wheeled Scraper Co. 45-yd. automatic air dump cars.
1 Geo. D. Whitcomb Co. 10-t. type B.J.D. gasoline locomotive with 6-cylinder, 105-hp. Beaver vertical engine. Speeds up to 9.6 mi. an hr.; drawbar pull 5000 lb. on level.
1 Robins Conveying Belt Co. 24-in. belt conveyor over bunkers; capacity 150 t. an hour at 300 ft. a minute; self-propelling tripper and 2-way discharge chute. Driven through Cleveland worm gear by 7½-hp. Fairbanks-Morse type H ball bearing motor.
Following conveyors by The Jeffrey Mfg. Co.
1 apron flight conveyor 36-in., 43-ft. centers; capacity 70 t. lump coal an hour at 12 ft. a min. Magnetic drum at head, both driven by 5-hp. Fairbanks-Morse, squirrel-cage induction motor.
1 belt conveyor to crusher, 36-in., 23-ft. centers, 18 deg. slope, 70-t. an hour lump coal at 200 ft. a min. Driven by same motor as apron conveyor.
1 bucket conveyor, 24 in. by 24 in., 128 ft. vertical centers, 24 ft. horizontal centers; 70 t. an hour at 50 ft. a minute; shaft safety lock; stationary tripper. Driven by 20-hp. Fairbanks-Morse type H ball bearing motor.

Air Preheaters, Fans, Draft Equipment

4 The Air Preheater Corp. Ljungstrom air preheaters, type C-16, with integral forced and induced draft fans, soot blowers, etc., each unit driven by a 100-hp. Allis-Chalmers motor type A.R.Y., 2300-v., 1800-r.p.m.; full voltage starting with Cutler-Hammer drum type controllers.
1 Mead-Peun Iron Wks. Co. steel stack, 8 ft. diameter, 100 ft. high.

Evaporators, Heaters and Other Water Treatment Apparatus

1 Permutit Co. 2 unit water softener, 1730 g.p.h. maximum cap.; working pressure 125 lb.; 14,400 gal. a day.
2 Chain Belt Co. Rex traveling water screens, 18-ft. centers, 6 ft. 4 in. wide, capacity 15,000 g.p.m. Driven by 2-hp. Allis-Chalmers type KT motors.
1 Croll-Reynolds Engineering Co. single effect evaporator; capacity 5000 lb. raw water an hour at 70 deg.; steam at 16 lb. abs., 250 deg. Evaporator condenser uses 210,000 lb. condensate at 135 deg. as condensing medium.
1 Croll-Reynolds Engineering Co. high-pressure, 2-pass, closed type bleeder heater, 200 sq. ft. surface to heat 250,000 lb. condensate from 210 to 250 deg. when supplied with steam at 135 lb. abs., 550 deg.
2 Croll-Reynolds Engineering Co. low-pressure, 6-pass, closed type bleeder heaters, each to heat 105,000 lb. condensate from 90 to 134 deg. when supplied with steam at 3 lb. abs., 141 deg. surface, each 500 sq. ft.
1 Worthington Pump & Machy. Corp., 8000-hp., 2-section, horizontal open feed water heater; 270,000 lb. water an hour; no oil separator; float-operated make-up valve.

Pumps

2 Worthington Pump & Machy. Corp. 4-in., 4-stage, type T.S. centrifugal boiler feed pumps; 500 g.p.m., 210 deg., 450 lb. pressure; equipped with 2½ in. angle type Mercon Regulator Co. excess pressure pump regulator. Direct driven at 2750 r.p.m. by 229-hp. Terry steam turbine taking steam at 325 lb., 700 deg.
2 C. H. Wheeler Mfg. Co. centrifugal circulating pumps, 20-in., Class N.C.; each 12,900 g.p.m., 15 ft. head, 440 r.p.m., direct-driven by 75-hp. Westinghouse type C.S., 2300-v., 450-r.p.m. motors.
1 Yeomans Bros. Co. No. ½ single electric bilge pump, 15 g.p.m., 76 ft. head, direct-driven by 3-hp. Westinghouse motor; for makeup water from reservoir.

With the exception of the auxiliary equipment noted above, all other auxiliaries in the plant, such as boiler feed and service pumps and low-pressure bleeder heaters, are located in the turbine room. This contains at present two 10,000-kw., 12,500-kv.a. turbo-generator units, designed to generate at 14,000-v., 3-phase, 60-cycles. The turbines take steam at 325 lb. gage, 700 deg. total temperature and operate at 1800 r.p.m. Exr.p.m., however, the turbine is automatically cut in to pick up the load. By adjustment of the governor spring on this turbine the load it carries can be varied to provide some control of the heat balance.

As noted above, each main turbine is bled at three points for feed water heating. The first point at 135 lb. abs. supplies steam to a 250,000 lb. an hour, 2-pass, closed type bleed heater; this heater takes steam from

Principal Mechanical Equipment in Bayside Station—Concluded

2 Chicago Pump Co. 1½-in. type L.I.C., vertical submerged type bilge pumps; each 60 g.p.m., 40 ft. head, direct-driven by 1½-hp. Baldor a.c. motors.
1 Yeomans Bros. Co. No. ½, 2-stage horizontal centrifugal evaporator pump; 25 g.p.m., 5-lb. pressure, 160 deg., direct-driven by 3-hp. G.E. motor.
2 C. H. Wheeler Mfg. Co. 4-in. type H. W., 2-stage centrifugal hotwell pumps; 300 g.p.m., 92 ft. head, direct-driven by 20-hp. Terry steam turbine at 1500 r.p.m.
2 S. F. Bowser & Co., Inc., oil filter pumps; one a Richardson-Phenix type U-3 duplex steam pump; other a 9-g.p.m., 30-ft. head centrifugal, driven by a ¾-hp. G.E. motor.
2 Worthington Pump & Machy. Corp. 5-in. double-suction centrifugal service pumps, 750-g.p.m., 120-ft. head; one driven at 1750 r.p.m., by 40-hp. G. E. motor, one driven by 40-hp. Terry steam turbine.
1 Goulds Pumps, Inc., deep well pump, single-acting brass ball valve cylinder, 50-g.p.m., belt-driven from a 3-hp. Westinghouse motor.
1 Nelson Machy. Co. deep well pump.
1 Nash Engineering Co. Jennings-Hytor heating return pump with double automatic control for 8000 sq. ft. radiation.

Turbines, Condensers and Auxiliaries

2 Allis-Chalmers Mfg. Co. turbo-generator units, type AT-4-42-69½. Each rated at 10,000 kw., 12,500 kv.a., 3-phase, 60-cycle, 14,000-v., 1800-r.p.m. Throttle pressure 325 lb., 271 deg. superheat, vacuum, 29 in. Steam bled at 135 lb., 17 lb. and 3 lb. abs. Gland water, 90 g.p.m. at 15 lb. gage.
James G. Biddle vibrating reed tachometers.
2 C. H. Wheeler Mfg. Co. semi-dual bank surface condensers, each 12,700 sq. ft. surface; 2-pass; spring supported. To condense 95,000 lb. steam an hour at 29 in. vacuum when supplied with 12,900 g.p.m. of 50-deg. condensing water. Equipped with C. H. Wheeler Mfg. Co. air meter.
2 C. H. Wheeler Mfg. Co. vacuum pump units, each unit consisting of two type T.C.A.-40 Radojet air pumps, each to remove 5.6 cu. ft. free air a minute. Interafter condenser cooled by main condenser condensate.
1 General Electric Co. motor-generator set for excitation: 100-kw., 275/275-v., d.c. generator, driven at 1160 r.p.m. by 150-hp., 2300-v., a.c. motor.
1 Duplex exciter set, 3 unit; 100-kw., G.E. 275/275-v., d.c. generator; direct-connected on one end to 150-hp., G.E., 1170-r.p.m., a.c. motor; direct-connected on other end to 100-kw. Terry steam turbine. Turbine picks up load automatically when motor speed drops to 1135 r.p.m.
1 S. F. Bowser & Co., Inc., No. 16-A oil filter, continuous bypass system, capacity filtration tank 180 gal., clean oil tank 380 gal., dirty oil tank 550 gal. Pump noted above.
2 Allis-Chalmers Mfg. Co. oil coolers, each 860-gal. capacity.
2 The Griscom-Russell Co. U-fin type air coolers for generator air, working pressure on tubes, 75 lb. To cool 36,000 c.f.m. of air from 136.7 deg. to 104 deg. with 1677 lb. of condensate at 90 deg. Motor-operated valves.

Miscellaneous Mechanical Equipment

1 Northwest Engineering Co. model No. 104 crawler crane; Twin City gasoline engine, 7¼ in. by 9 in., 45-ft. boom, high gantry, one yard Page class C dragline bucket, also clam shell.
1 Whiting Corp. 100-t. turbine room crane; span 53 ft. 6 in., lift 50 ft., travel 100 ft. a minute. Auxiliary hoist, 10 t. General Electric Co. motors.
1 Otis Elevator Co. single-wrap, traction-geared passenger elevator; push button operated, electro-magnetic control; capacity 1800 lb., 100 ft. a minute.
2 The Yale & Towne Mfg. Co. hoists: one 2-t. spur-geared chain block hoist, 16-ft. lift, for boiler room; one 3-t. spur-geared chain block hoist, 57-ft. lift, for air preheaters.
1 Fairbanks, Morse & Co. 125-t. type S-12 railroad scale.
2 Crane Co. motor-operated gate valve units each consisting of five gang-operated, 4-in., rising-stem gate valves driven by Crane G. E. valve operators with central control station; for use on generator air cooler.
5 S. F. Bowser & Co., Inc., 120-gal. unit outfits for storage of lubricating oil.
1 General Electric Co. 5.75-kw. motor-generator set for charging magnetic pulley and operating pulverizer feeder motors, No. 2 boiler steam flow meters, air preheater temperaure recorders and draft indicators, multipointer draft gages, feed water meter, portable meter, V-notch water meter, etc.....Bailey Meter Co.
Condenser leakage meter.....Esterline-Angus Co.
Recording pressure gage.....The Foxboro Co., Inc.
Recording thermometers—Leeds & Northrup, Taylor Instrument Cos., C. J. Tagliabue Mfg. Co.
Tachometers and frequency indicators.....James G. Biddle
Pressure reducing valves.....Mercon Regulator Co.
Steam pressure gages, vacuum gages—Manning, Maxwell, Inc., Crosby Steam Gage & Valve Co.
Piping—H. P. steam and boiler feed piping.....Crane Co.
Low pressure steam and water.....Crane Co.
Valves:
High pressure steam.....Crane, Co., The Edward Valve & Mfg. Co.
High pressure water.....Crane Co., The Edward Valve & Mfg. Co.
Small forged steel valves.....Crane Co., The Edward Valve & Mfg. Co.
Motor-operated valves—Crane Co. with Crane motor operators.
Expansion joints:
Condenser circulating water piping, Goodyear Rubber Co.
Condenser drain lines.....Crane Co.
Subway grating and vizabledge safstep, Irving Iron Works
Stairs and structural steel and boiler breeching.....Lakeside Bridge & Steel Co.
Ventilators and skylights.....H. H. Robertson
2 Portable pneumatic sweeping outfits..American Rad. Co.
Air compressors:
1 Ingersoll-Rand Co. 35-c.f.m., vertical duplex air compressor, direct connected to Westinghouse 220-v., 15-hp., 900-r.p.m. motor.
1 Ingersoll-Rand Co. 115-c.f.m. vertical duplex air compressor direct connected to Westinghouse 220-v., 40-hp., 600-r.p.m. motor.
Atmospheric relief valves.....Atwood & Morrill
Steam traps.....Armstrong Machine Works
Thermostatic diaphragm valves.....Taylor Instrument Cos.
Ash gates.....Beaumont Mfg. Co.
2 Dump cars for handling ash, 54 cu. ft. each.....H. B. Sackett Screen & Chute Co.
Machine shop equipment.....Niles Tool Works
Compressed air suction torches.....Hanck Mfg. Co.
Sluice gates.....Coffin Valve Co.
Dustless coal valves, four 14-in.....Henry Pratt Co.
Pump governor (1).....The Fisher Governor Co., Inc.
Fire brick and tile.....Missouri Fire Brick Co.
Wall radiators and brackets.....American Radiator Co.

citation of these units is from either of two separate exciter sets installed on the condenser floor as shown. One exciter set is a 100-kw., 250-v. motor-generator set. The other consists of a 100-kw., 250-v., d.c. generator with a 150-hp., 2300-v., 1170 r.p.m. motor direct-connected to one end of its shaft and a 100-kw. noncondensing steam turbine direct-connected to the other. An automatic control arrangement starts the motor of this unit at full voltage, this motor driving the exciter under normal conditions. If its speed drops to 1135

both turbines. The second at 17 lb. abs. supplies the evaporator. The third, at 3 lb. abs. supplies two closed type low-pressure bleeder heaters at 105,000 lb. an hour capacity each.

Each turbine exhausts into a 12,700-sq. ft. two-pass surface condenser, connected directly to the turbine exhaust flange and supported on springs. Owing to the arrangement of circulating water piping from the circulating pumps, which are located just in front of the condensers, as shown in Fig. 1, expansion joints are

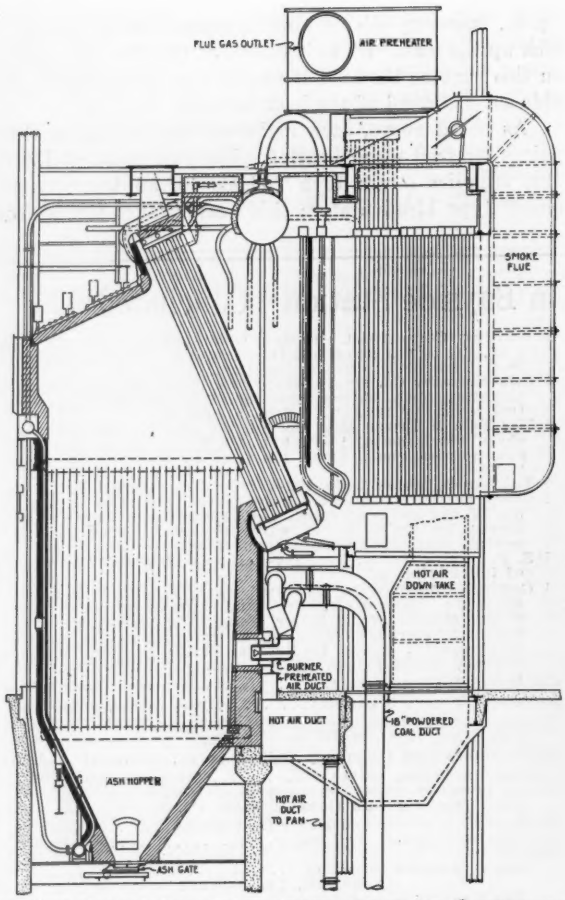

FIG. 6. COMPLETE SECTION THROUGH BOILER NO. 2 SHOWING FURNACE CONSTRUCTION AND ONE TYPE OF BURNERS USED

inserted in this piping. These joints are rubber sleeves similar to those used in dredge discharge lines. Steam jet air removal pumps are used; these are in a somewhat unusual position, being located on the main turbine platform beside the turbine cylinder. The principal reason for doing this was that, if they were placed on a framework above the pumps so that they would drain by gravity as usual, they would be somewhat inconvenient for the pump operator below. With the present arrangement, however, these air pumps are easily accessible to the turbine operator. A motor-driven centrifugal circulating pump supplies each condenser with 12,900 g.p.m. With this water at 50 deg. the condenser is designed to condense 95,000 lb. of steam an hour at 29 in. vacuum.

The circuit of the feed water is as follows: generator air cooler, steam jet air removal equipment, low pressure bleeder heater, evaporator, evaporator condenser, open heater and high-pressure bleeder heaters, emerging

FIG. 8. ALL BOILER CONTROLS ARE GROUPED ON THIS BOARD, LOCATED ON THE BURNER FLOOR

from the latter at about 250 deg. and entering the boiler through the heater section.

The principal feature of interest in connection with this system is the arrangement of valves to control the operation of the generator air coolers. Each generator is served by a U-fin type air cooler designed to cool 36,000 c.f.m. of air when supplied with 1677 lb. a minute of condensate at 90 deg., a diaphragm valve, controlled automatically by a thermostat, is provided which will bypass the condensate back to the condenser in case the amount of condensate is not great enough to absorb the generator losses. In addition, a group of five valves, geared together and operated from one motor, may be used in emergency for switching from condensate to service water for cooling air. These valves are shown in Fig. 4, which is a diagrammatic, not an actual, representation of the piping.

Makeup water for the boilers is evaporated in a two-shell single effect evaporator with a capacity of 5000 lb. of raw water at 70 deg., taking steam direct from the second bleed point of the turbine at 17 lb. abs., 250 deg. Vapor from this evaporator is condensed in a 745-sq. ft. evaporator condenser. The unit is fully equipped with relief valves and float control. To control the heat balance during light loads, arrangements are made for

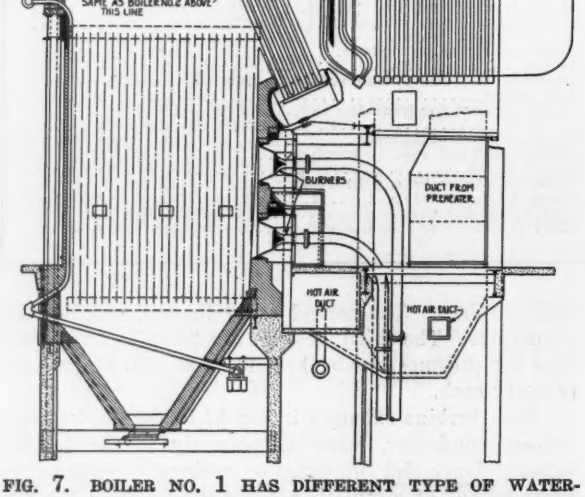

FIG. 7. BOILER NO. 1 HAS DIFFERENT TYPE OF WATER-COOLED WALLS AND BURNERS, BUT BOILER ITSELF IS THE SAME

the evaporator to take steam from the auxiliary exhaust header. To avoid scaling the evaporator, a zeolite water softener and filter of 1730-g.p.h. capacity treats all water before it goes to the evaporator.

Raw water is stored in a 10,800-gal. storage tank on the roof of the plant and a similar tank holds softened water in storage. Evaporated water for makeup is stored in a concrete tank below the basement floor level. Intake water screens are washed with service water. Water for lavatories and drinking fountains is obtained from a deep well. Various service pumps and well pumps, as noted on the accompanying list of equipment, supply the various parts of the plant. Several bilge pumps take care of the drainage of low points in the basement.

Figure 4 shows diagrammatically the complete piping system of the plant and Fig. 2 some of the principal piping as installed. Steam lines from boilers are led to a short manifold but there is no main steam header. From this manifold the various units take steam by direct lines.

Complete facilities for filtering and cooling lubricating oil are provided by a continuous bypass type oil filter and two 860-gal. oil coolers. Lubricating oil is stored in unit outfits of 120-gal. capacity each, the units consisting of barrel track, cradle and ½-t. hoist.

In the turbine room is installed a 100-t. traveling crane with main hoist speed of 6 ft. a minute and an auxiliary 10-t. hoist with a speed of 20 ft. a minute. Crane travel is at 100 ft. a minute. For handling material in the boiler room a 2-t. spur gear hoist is provided and other larger hoists are installed to handle the air preheater elements. A railroad track runs into the turbine room at the condenser floor level.

Machine shop facilities have been provided for making any usual repairs to equipment that can be made in the plant. This opens directly off the turbine room floor and the watch engineer's office is directly above it, with a stairway leading to the turbine room and windows looking into both boiler and turbine rooms. This office and shop are located between the main power house building and the annex which contains coal crushing and handling equipment. This arrangement was adopted so that good light could be secured in the boiler room, a feature too seldom considered in power house design.

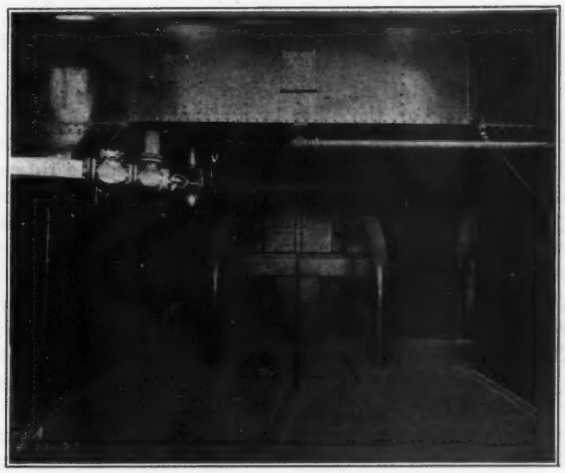

FIG. 10. TURBULENT BURNERS OF NO. 2 BOILER ARE SET IN A STRAIGHT LINE, ONE MILL SUPPLYING EACH ALTERNATE PAIR

All controls for the boilers are on a central board located at the burner level, as shown in Fig. 8. Boiler control is almost entirely manual, the only automatic equipment being the feed water level regulators. On a central panel are grouped controls for the pulverizing mill motors and mill feeder motors, soot blowers, draft gages, boiler meters, steam gages and damper controls for forced draft and uptake. The dampers are opened by weights and closed by cable wrapped on drum and an 8-in. diameter ratchet wheel gives close control of these.

As noted, auxiliaries are driven in some cases by motors and in others by non-condensing steam turbines. The combinations of these are worked out in such a way that sufficient turbine exhaust at about 17 lb. absolute is available to fit into the heat balance, and so that

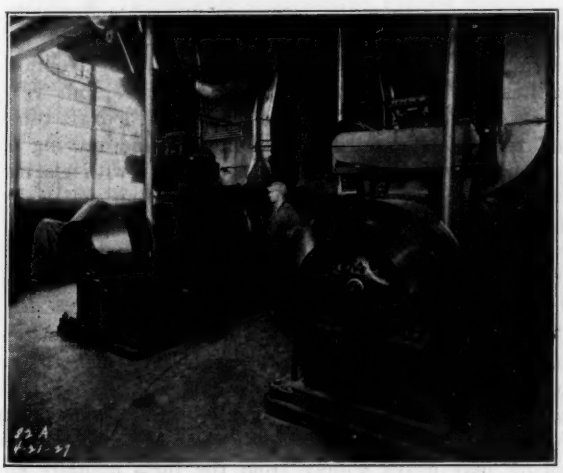

FIG. 9. EACH OF THESE UNIT PULVERIZERS CAN PULVERIZE ENOUGH COAL TO CARRY THE BOILER AT ABOUT ⅔ OF ITS FULL CAPACITY

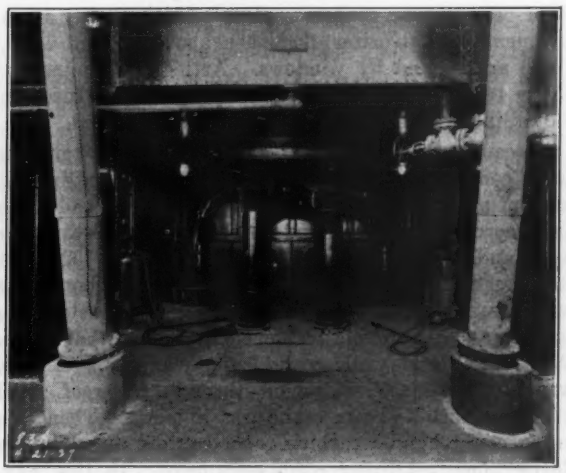

FIG. 11. TURBULENT BURNERS OF NO. 1 BOILER ARE SET ONE PAIR ABOVE THE OTHER, EACH PAIR BEING SUPPLIED BY ONE MILL

essential auxiliaries are steam driven and not subject to electrical disturbances. Circulating pumps and exciters are driven by 2300-v., a.c. motors arranged for across-the-line starting. One low service pump is driven by a 220-v. motor, the other by a steam turbine. Boiler feed pumps, hotwell pumps and one exciter are driven by steam turbines, exhausting at 17 lb. absolute to an exhaust header which normally supplies steam to the open feed water heater, with special arrangements as noted for supplying the evaporator when the turbine load is low.

Turbine lead valves are motor-operated, together with a sectionalizing valve on the main steam manifold. Closing buttons for these valves are placed on the turbine control boards, in addition to the control stations in the boiler room.

For cleaning about the plant two portable pneumatic cleaning outfits are provided and compressed air is supplied by two compressors for general use.

At the west side of the building is the electrical gallery and at the rear of the station is the outdoor substation. Details of the electrical equipment are given in another article elsewhere in this issue.

The power plant building itself is of steel framing with tile walls and has a ground area of 15,000 sq. ft., including electrical galleries. Tile walls are matte-faced, of a dark red shade, and are trimmed with precast cement, presenting a most attractive appearance. The entire roof is of concrete slabs with cork insulation. Over this is 1 in. of Celotex and a 5-ply Barrett tar and gravel roof. Turbine room gallery has a tiled floor and boiler room floors have a patented top coat; floors of corridors and offices have red cement finish. No wood is used in any parts of the building; doors are of fireproof construction with steel frames, sash is of steel and stairs are of non-slip treads and housed in. Furniture is metal and the design throughout is modern and fireproof. Motor shields, guards, couplings, record files and miscellaneous furniture and accessories were made in Green Bay.

The plant is well lighted. A large part of the wall space is window. The turbine room is lighted on two ends and the boiler room on side and end. The turbine room basement or condenser floor and the boiler room basement or pulverizer floor are above ground level, hence are lighted by windows. Artificial illumination of the turbine room is provided by lighting fixtures on the ceiling with other spot fixtures where needed.

Because of the excellent work of the construction crew, construction of the plant proceeded rapidly and without any friction or accidents. A railroad had to be built across marshy ground to the plant. Excavation work and foundation were begun in March, 1926 and steel erection was begun in July, 1926. Good clay strata were available for foundations about 5 ft. below the surface and no trouble was encountered on that score. While steel and walls were being erected, a derrick was used to place equipment through the roof until after the turbine room crane was in place. Then this crane could handle turbine room equipment while the derrick handled boiler room equipment. In this way, by the time the roof was ready to go on, practically all the major equipment had been put in place. The large amount of rain in the autumn of 1926 held up brickwork somewhat but the first boiler was lighted on Nov. 1 and the first turbine unit placed in operation Dec. 1, 18 weeks after steel erection was begun.

Bayside station was designed by the engineering department of Byllesby Engineering & Management Corp. for the Wisconsin Public Service Corp., a subsidiary of Standard Gas & Electric Co. Mechanical engineering was in charge of H. Boyd Brydon, assisted by H. S. Whiton. Electrical design was supervised by R. M. Stanley. J. L. Hartney is chief engineer of Bayside station; A. G. Carson is chief engineer of power plants of the Wisconsin Public Service Corp. H. H. Fisher is superintendent of construction of the station. To these men and to many other members of the company's engineering department we are indebted for cooperation in visiting the plant and in obtaining data and illustrations used in this article.

Coffer Dam Construction

LITTLE MATERIAL has been published on the subject of coffer dams, probably because details are less the result of theoretical design than the result of individual experience and judgment necessary to meet the varying physical conditions. Speaking before the Engineers Society of St. Paul on the construction of hydroelectric projects, N. A. Selmers pointed out that rock-filled cribs sheeted on the water side with steel piling are still in wide use. Its greatest weakness is the liability of undermining by swift currents, as very few solid rock sites have the ledge actually exposed and even in swift water there is usually an overburden of boulders.

In pervious bottoms Wakefield piles supported by round piling and bracing are often used. Wakefield sheeting is much more economical than steel sheeting but requires care in driving. It can be salvaged much easier than steel and this type of dam with proper penetration has the distinctive advantage of reducing water pumping and flow of saturated sand commonly referred to as "quick sand."

In dam construction, the self supported type of coffer dam is the most popular. As for the job, they are better adapted than the internally braced coffer dam. One of the chief objections to this type is that the bracing interferes and slows up concrete construction, an item of no consequence in bridge work, but very important in the installation of complicated draft tubes and wheel pits requiring the handling and moving of temporary bracing. Pumping is handled with electric pumps whenever possible, as such operation materially reduces the labor. Various types of pumps have their individual advantage but, the use of the submerged type of centrifugal pump is usually favored on account of the simplicity and elimination of priming troubles.

All sites should be tested carefully with borings made by an experienced company. Even when this is done, however, the element of chance will exist, as many river bottoms vary materially between holes taken every 50 ft. Further, the analysis of the results from boring may differ widely from the facts actually encountered, so that it is well to make a liberal allowance over normal cost to cover changes that may arise in foundation conditions.

Pioneer Experiences at Edgar Station

THE MAJORITY OF DIFFICULTIES PREDICTED FOR THIS PIONEER HIGH PRESSURE INSTALLATION DID NOT MATERIALIZE. BY G. R. DAVISON* AND R. E. DILLON†

TWO YEARS ago, on the seventeenth of January, 1925 the Edgar Station of The Edison Electric Illuminating Co. of Boston first went into commercial service. At the time plans for this station were under way less than half a dozen power stations in the United States had been put into operation using steam pressures as high as 400 lb. and when the 1200-lb. pressure turbine station was started it was the highest steam pressure on record for commercial use.

Two years of operating experience has served to confirm the reasons which led to the adoption of 1200 lb. pressure and the expectations for the equipment have been entirely fulfilled. No unusual troubles have developed due to the pressure. Several precautionary measures were taken in the original installation to insure against unknown factors and it may be interesting to relate some of this pioneer experience.

SELECTION OF ECONOMIC PRESSURE

In connection with this object it may be of interest to review briefly some of the considerations which led to the selection of the steam conditions and at the risk of repeating what has appeared at length in previous articles a brief outline will be given of the original studies made in this connection. With this brief description in mind some of the experiences will be better appreciated.

Since it has become the general policy to use the highest practical steam temperatures this item needs no mention and the influence of pressure becomes of chief interest at this time. Efficiency of steam generation may be considered constant over a reasonable range of pressures, since this is strictly a matter of varying the relation between economizer and boiler surface. The basis for the selection of the economic pressure is in the question of the utilization of the steam and the effect on the turbine.

In an N. E. L. A. paper prepared by I. E. Moultrop and R. E. Dillon and presented at Poland Springs in September, 1926, a chart was given showing the relation between efficiency and initial steam pressure in a turbine. This chart is reproduced and shown in Fig. 1. The figures are based on fixed initial temperature at 700 deg. F., 1 in. of mercury back pressure and two stages of extraction for feed water heating.

When no reheating is employed, the use of higher pressures is attended by an advance in the formation of the dew point to earlier stages of the turbine with corresponding increased loss. Curve C shows the thermal efficiencies with increasing pressure and it will be noted that from an operating efficiency viewpoint the economic pressure is at 600 lb. True economic results take into account capital charges and under the conditions when reheat is not employed these modify the figures so that pressure beyond 400 lb. is not justified.

Reheat applied to one point of expansion of the steam through the turbines serves the purpose of retarding the appearance of the dew point to later stages and raises the efficiency. Curve F indicates an increment in efficiency for each increment in pressure, in contradistinction to curve C.

There has been a tendency in some quarters to doubt the economic value of reheating the steam at one point. Considered from the purely theoretical point of view the Rankine efficiency shows little gain from reheat so applied. The main feature to be noted, however, is that the losses of each stage of the turbine increase very rapidly with the appearance of moisture. The value of reheating therefore lies in maintaining the steam free from moisture through as many stages as possible. That the conditions through the turbine for 1200 lb. pressure can be made to approach very nearly

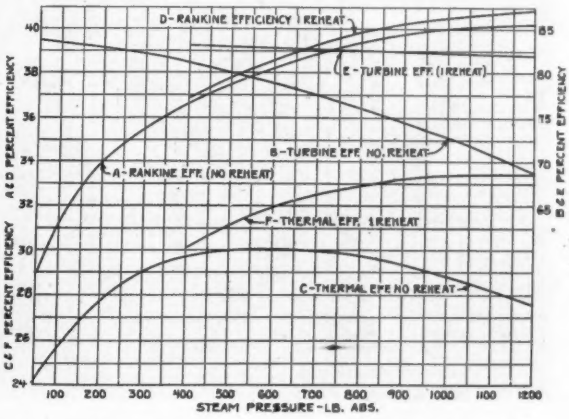

FIG. 1. INCREASED EFFICIENCIES DUE TO REHEATING BECOME OF GREATER IMPORTANCE AT HIGH PRESSURES

the condition for 350 lb. pressure with reheat applied at one point is indicated by curve E, Fig. 1.

INFLUENCE ON CAPITAL COST

Speculation upon the cost for high pressure equipment has led to the popular belief that capital figures are unfavorable to high pressure equipment. This has not proved to be the case at Edgar Station. It is a fallacy to compare relative costs and fail to take into account various offsetting features. This may be pointed out in a few examples. Undoubtedly the cost per square foot of surface of the 1200-lb. pressure boiler is greatly in excess of the 350-lb. pressure boiler. With the increased cycle efficiency possible, however, this boiler has an increased kilowatt output of 25 per cent over the lower pressure boiler and the cost is further offset by approximately 20 per cent reduction in required condenser surface. The reduction in required turbine auxiliary capacity on the other hand cannot be credited to the move without balancing against additional boiler feed pumps with no material gain.

Descriptions of Edgar Station have been given many times over in various articles and a brief statement in relation to the equipment is all that is required here. The present installation includes one 15,732-sq.

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ft. Babcock & Wilcox cross drum boiler with a convection superheater installed producing steam up to 1200 lb. pressure and 700 deg. F. temperature. It is fired by a Taylor underfeed stoker and a secondary superheater or reheater and a steel tube economizer are parts of the unit.

The high pressure turbine exhausts at 360 lb. pressure and has a capacity of 3150 kw. Since there is but one of these and the 350-lb. pressure equipment includes two 30,000-kw. units, only a part of the steam supply for the 350-lb. pressure mains is expanded through the high pressure turbine, the remainder being supplied by 350-lb. pressure boilers.

Steam from the high pressure boiler is supplied to the high pressure turbine. The high pressure is regulated to a point controlling the load desirable to carry on the turbine. The exhaust pressure from the unit is

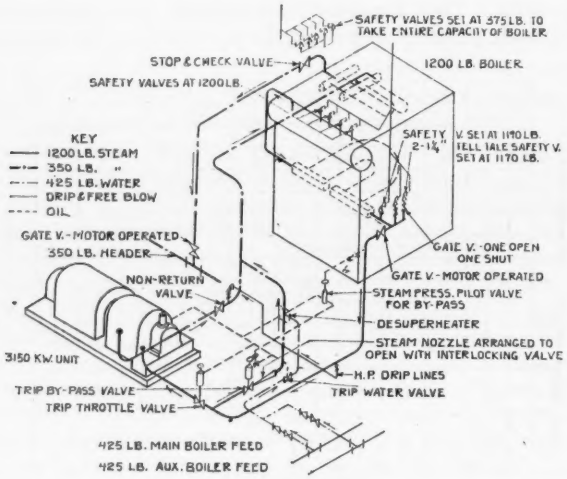

SAFETY VALVES SET AT 375 LB. TO TAKE ENTIRE CAPACITY OF BOILER
STOP & CHECK VALVE
1200 LB. BOILER
SAFETY VALVES AT 1200 LB.
KEY
1200 LB. STEAM
350 LB. "
425 LB. WATER
DRIP & FREE BLOW
OIL
SAFETY V. SET AT 1140 LB.
TELL TALE SAFETY V. SET AT 1170 LB.
GATE V.-MOTOR OPERATED
350 LB. HEADER
GATE V.-ONE OPEN ONE SHUT
NON-RETURN VALVE
GATE V.-MOTOR OPERATED
STEAM PRESS. PILOT VALVE FOR BY-PASS
DESUPERHEATER
STEAM NOZZLE ARRANGED TO OPEN WITH INTERLOCKING VALVE
3150 KW. UNIT
H.P. DRIP LINES
TRIP BY-PASS VALVE
TRIP WATER VALVE
TRIP THROTTLE VALVE
425 LB. MAIN BOILER FEED
425 LB. AUX. BOILER FEED

FIG. 2. PIPING DETAILS FOR THE 1200-LB. SYSTEM ARE WELL BROUGHT OUT BY THIS ISOMETRIC DRAWING

returned to the reheater where superheat is restored and the steam is then used to supply the 350-lb. pressure turbines.

Experiences Covering 2 Yr. Operation

If there is one feature of high pressure equipment which has been looked upon with misgivings it is in the speculated wear on valve seats. Experience in this respect, however, has proved a revelation and no unusual erosion in valves has taken place. For the purpose of relieving wear on safety valves there was mounted in a manifold to which the superheater outlet is connected, two additional safety valves each provided with globe shut-offs. These valves were set to blow at a lower pressure than the main valves on the superheater by this means providing opportunity for saving operation on the main valves. These have been found unnecessary, the safety valves showing no undue signs of wear.

Another precautionary measure was adopted in equipping the check valve installed in the exhaust line from the high pressure turbine with an automatic trip, the purpose being to insure doubly against reverse flow. The mechanism was removed as it gave trouble and the simple swinging check proved to be entirely effective.

Valve trouble in general due to high pressure has failed to materialize. The valve which is installed in the bypass to the high pressure turbine was set partially open much of the time at first in order to load up the high pressure boiler. During this time this valve was subject to wiredrawing for extended periods and yet

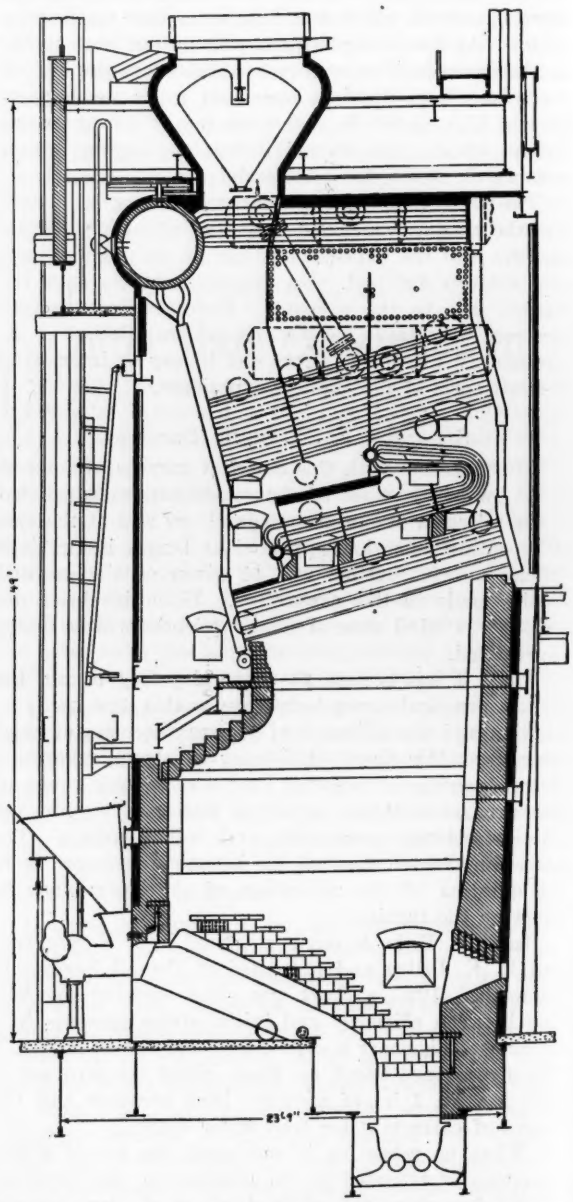


FIG. 3. IT HAS NOT BEEN NECESSARY TO OPERATE THE MOVABLE BAFFLE ORIGINALLY INSTALLED TO PROTECT THE REHEAT COILS

upon examination after 1800 hr. of such service, no signs of wear were noted. Such valve leakage as has occurred has apparently been overcome by grinding in the seat rings. No trouble developed in castings and fittings due, without doubt, to the X-ray inspection made before installation.

Reheater tubes installed as a part of the high pressure boiler were equipped with a movable baffle intended

to prevent any dangerously high steam temperature from developing. This, however, has not occurred and the baffle is left in the position for maximum reheat under all conditions. The temperature range, it will be understood, is a factor of the design and location of the superheater and reheater but the success with this installation indicates that designers will be able to avoid dangerous temperatures by following in the line of customary methods. With no dangerous temperature encountered it is also possible to dispense with the desuperheaters installed in the high pressure turbine bypass.

Water Slugs Have Caused Some Difficulty

At the time of installation, automatic feed water regulators had not been developed for such high pressure and it was necessary to control the feed manually. This has been undesirable from an operating point of view, and has interfered with the normal use of the automatic boiler control in connection with the unit. Complicating this matter also, is the comparatively small boiler drum. Furthermore, due to the location of the connections, some peculiarities in water levels have been noted and first fears that trouble might develop due to carrying over slugs of water were not ungrounded. The matter has not proved serious, but water slugs have caused the high pressure unit to trip out and a feed water regulator developed in the meantime for 1200 lb. pressure has been put in service.

In the high pressure boiler some slagging has occurred. The lower deck of closely spaced 2-in. tubes has given serious trouble. No arrangement was made for removing slag at this point while in operation and it is necessary to shut down the boiler and get inside and knock the slag off. Furthermore, due to the close spacing of the tubes, the fan power is high and the slag formation quickly limits the capacity of the boiler. This trouble has resulted in cutting down the capacity to some extent and in limiting the length of service to a period of a few weeks. The remedy already in use elsewhere is to provide means for removing the slag without shutting down. In the early period of service the slag screen tubes nearest the furnace warped a moderate amount under continued service. This trouble has not grown and developments are being closely watched.

Pressed Asbestos Solves Gasket Troubles

Some gasket trouble has been noted on the high pressure equipment, notably on the economizer. This also has occurred on low pressure boilers and economizers. Metallic gaskets failed and were replaced with pressed asbestos gaskets. This has apparently solved the question, although news from other stations indicates that asbestos has given trouble and has been replaced satisfactorily with soft copper.

Three or four cases regarding high pressure turbines come up for discussion. The machine was first fitted with carbon packing installed outside of the labyrinth packing. The first case of trouble arose before the machine was in commercial operation when the carbon and the radial diaphragm packings were found damaged, and the thrust bearing wiped. The carbon packing was replaced by labyrinth packing, the thrust bearing was replaced by one of larger size and the radial diaphragm packing was replaced by axial packing. Since this time the packing and the thrust have shown no evidence of trouble.

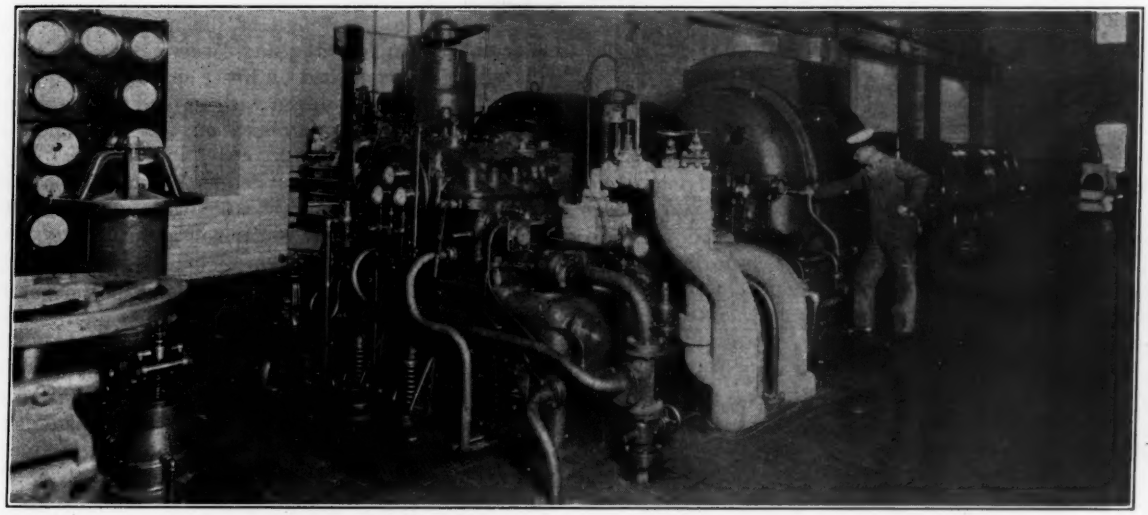


FIG. 4. TURBINE END OF THE 3000-KW. 1200-LB. TURBO GENERATOR AT EDGAR STATION

Economizer Corrosion Has Been Rapid

After 1800 hr. of service the high pressure turbine was opened up for inspection. It was found that the first two and last two rows of buckets were bent. No sign of trouble was evident with the nozzles. There was also noted a light deposit of iron oxide throughout the machine; this same deposit was found to be present in valve fittings and in all boilers as well. The iron oxide apparently originated in the economizer where rapid corrosion has taken place, probably due to insufficient deaeration of feed water. Slight signs of pitting were noted in the boilers and in the high pressure turbine. The buckets on this occasion were straightened and the machine was put back into service. No definite finding has been made as a cause for the

bent buckets, although several theories have been advanced.

One change has been made in the high pressure generators. The field of the generator as originally installed was equipped with induction bars imbedded in the laminations. This was done in order to make it simpler to synchronize the machine. Vibration developed and this was attributed to the induction field. Meanwhile, experience demonstrated that there was no difficulty in governing and synchronizing the machine, so the original field was replaced with a solid field having no squirrel cage winding and the vibration was eliminated.

Description of Equipment to Be Installed

An extension to Edgar Station is now under way. Although the original layout left it possible to abandon development of the high pressure equipment without material alteration of the main features of operating

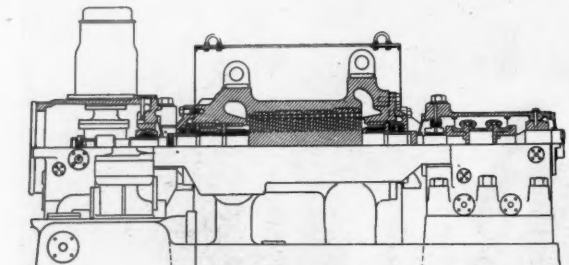


FIG. 5. IN THE HIGH PRESSURE TURBINE, 1200 LB. STEAM IS EXHAUSTED AT 350 LB. BACK PRESSURE

design, the success of the equipment has led to carrying the installation further. Consequently the new extension will include two 1400-lb. pressure boilers and one high pressure turbine of 10,000 kw. capacity exhausting at 360 lb. pressure for reheat and returning to the 350-lb. pressure mains to supply one single shaft turbine of 65,000 kw. capacity. This latter turbine will be bled at three points for feed water heating and a fourth stage of heating will take steam from the exhaust of the high pressure turbine. It is interesting to note that this is to be at the highest pressure that has yet been attempted for this purpose.

Special Features in New Equipment

As a result of experience with the original high pressure equipment several features have received special consideration. The original equipment consisted of a single installation and no provision was necessary for operating the equipment in multiple. As an instance of this, the loading of the present high pressure turbine can be accomplished by controlling the pressure of the 1200-lb. boiler. On the new equipment the high header will be maintained at constant pressure and the throttle to the high pressure unit will be governed from the pressure in the low pressure header. The bypass to the turbine will be equipped with a valve arranged to open when the pressure in the low pressure header reaches a predetermined point, but not effective until the turbine throttle is wide open. The turbine throttle will trip on overspeed in the usual way and the bypass valve will be geared by interconnection to open simultaneously with the closing of the throttle.

Another feature introduced by multiple operation is in connection with the division of load on the reheaters installed with the two new boilers. These will operate in parallel and in order to provide an indication so that distribution of the flow may be controlled, a Bailey meter will be installed in each reheater outlet as well as in each boiler outlet and suitable valves will be provided for the purpose.

In the present equipment, a check valve was installed in the exhaust of the high pressure turbine for the purpose of preventing a reverse flow through the turbine from the bypass. This in practice has been found unnecessary and will be omitted in the new installation.

A change in the design of the new high pressure boiler will aid in reducing slag formations on the tubes. This will be accomplished by wider spacing of the tubes. The boilers will be equipped with feed water regulators, development having progressed on this line since the original installation.

These are some of the details in connection with the high pressure equipment which are assured at this time. Other changes are under consideration.

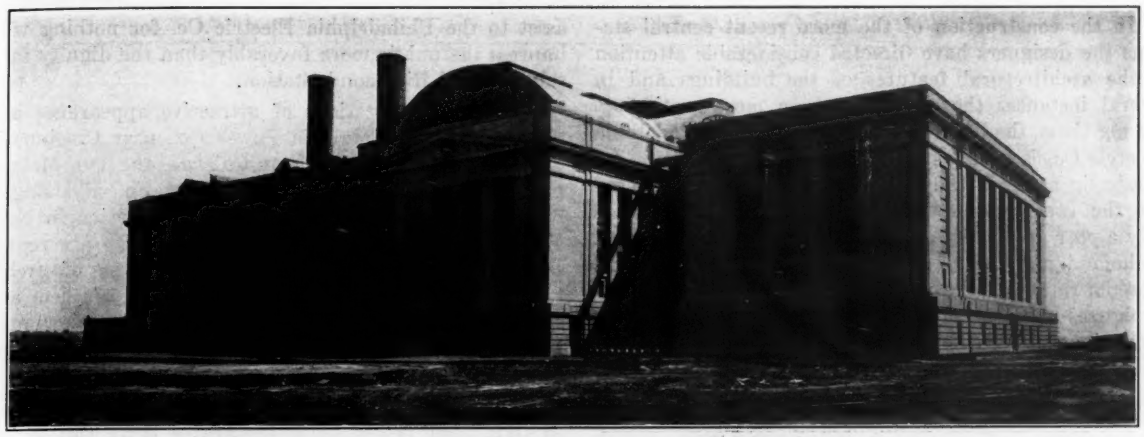
Aggregate refining capacity of the petroleum refineries of the United States continues to increase, although the number of refineries has decreased, says the United States Bureau of Mines, Department of Commerce, as a result of a statistical survey conducted by G. R. Hopkins, associate petroleum economist, as of Jan. 1, 1927. On that date there were 465 completed petroleum refineries in the United States with a total daily crude oil capacity of 3,061,007 bbl. In addition, seven refineries, with a potential capacity of 61,000 bbl. were under construction. Of the completed refineries, 327, with a capacity of 2,834,282 bbl. or 93 per cent of the total capacity were in operation.

Comparison with the figures of a year ago reveals that during 1926 there was a net decrease of 45 in the total number of complete refineries, but an increase in total capacity of 208,040 bbl.

The refinery industry in the United States during the past year has furnished a good example of the working of the law of the survival of the fittest, the Bureau of Mines points out. Most of the refineries dismantled in 1926 were constructed during the boom times of 1920, apparently in the hope that the price of gasoline would remain at the war-time level. Unlike most other commodities, gasoline declined sharply in price, one of the chief reasons being the over-supply.

Copies of the 1927 directory of refineries of the United States may be obtained from the Bureau of Mines.

At the Hilger and Hagedorn pits of the Ewald Coal Mining Co., Germany, boilers are fired by pulverized coal, which is prepared in a pulverizing plant located near a coal screening installation some distance from the boiler plant to enable pulverized fuel to be supplied to other consumers. Before being pulverized the coal is dried in a cylindrical drum heated in hot gases in a furnace fired by waste wood and coal.



Attractive Power Plants Need Not Be Costly

SMOOTHNESS OF LINE, HARMONY AND GOOD PROPORTION FAR MORE IMPORTANT THAN COMPLEX ORNAMENT AND COSTLY MATERIAL

IT IS A peculiar human trait that moves many people to associate beauty with costliness. If a thing is attractive it is unconsciously assumed to be costly or, reversing the idea, if a thing is costly it is a foregone conclusion that it is beautiful. It was this line of reasoning no doubt that led a highly successful bootlegger in a certain Illinois town not long ago to install solid gold door knobs and fittings in the mansion he built for himself. With due respect for his ability in his profession, we cannot admire his artistic instincts. He labored under the delusion that solid gold door knobs were more beautiful than bronze, simply because gold is more expensive.

Gaudiness, over-ornamentation, complexity, mass, extreme contrast is never beautiful, no matter in what respect. These qualities may impress and hold the attention for a short time but prolonged association with them tires and dulls our perceptions. Beauty is associated with simplicity, harmony and good proportion, and these things are never costly.

Nevertheless, the prevailing idea that beauty in architecture is expensive is no doubt the reason the average power plant is so entirely devoid of any quality that might be considered attractive. The instant architectural embellishment is mentioned to a power plant builder he has visions of granite or marble colonnades, hand-carved capitals and elaborate pediments, gold-plated smoke stacks and an empty treasury. "No!" he shouts, "this is a power plant we're building, a thing of utility and revenue, not an art gallery. We can't afford to waste the stockholders' money by such foolish extravagance." And then he proceeds to specify white tiled walls and red tile flooring and brass railings for the turbine room. What possible return to the stockholders can he see in an investment in tile walls and flooring? Certainly plain concrete walls and floors would serve equally well, and iron railings would be stronger.

The trouble with this executive is that he doesn't know the difference between the beauty of simplicity and the impressiveness of ornament. As has been pointed out in previous articles on this subject, attractive power plant structures can be built of plain brick and concrete at a cost little greater than that required to build an ugly plant of the same materials. The good or bad appearance of any structure is due not so much to the kind of materials used in its construction as in the manner in which the material is used. Symmetry and proportion are far more potent factors than marble, bronze and tile.

Let us take a typical example. In Fig. 3 is shown an industrial power plant of recent construction. As a thing of beauty it certainly can claim no laurels. It is just about as drab and ugly as any structure could be and, when it was designed, we doubt whether over 5 min. were spent in considering its appearance. From the viewpoint of utility, this plant may be very successful; its equipment may be highly efficient, but it adds nothing to the beauty of the landscape. All that can be said for it is that it protects the machinery from the weather.

In Fig. 4 we have taken this same plant and, while preserving the same general form and dimensions, have by the addition of a cornice and a few simple trimmings and a little attention to the character of the windows, transformed it into a structure which if not beautiful is, at least, of pleasing design. Naturally this latter building will cost more but not a great deal more, and if the builder of this plant doesn't think the additional money well spent, he doesn't know a great deal about advertising. The advertising value of an attractive building is usually worth the extra cost of making it attractive.

There are thousands of industrial power plants of the type shown in Fig. 1 in this country—mere walls and a roof built over the machinery. Industrial power plants are the worst offenders, first, because of their much greater number than central station plants and, secondly, because of their auxiliary character in the industries they serve. Central stations, however, are not to be considered free from criticism. There are a number of exceptions but the appearance of the general run of central stations is almost as bad as that of the industrial power plants.

In the construction of the more recent central stations the designers have directed considerable attention to the architectural features of the buildings and in several instances the result has been most gratifying. Among these, the Richmond Station of The Philadelphia Electric Co. is perhaps the most notable exception. Its classic lines are already familiar to engineers throughout the country, notwithstanding the fact that it is only a year and a half old and only one-third completed. Richmond gives one the impression of a library or a museum rather than a power station and, while we have no figures upon which to base our judgment, the money spent in making Richmond Station attractive cannot have been more than a small fraction of the total cost

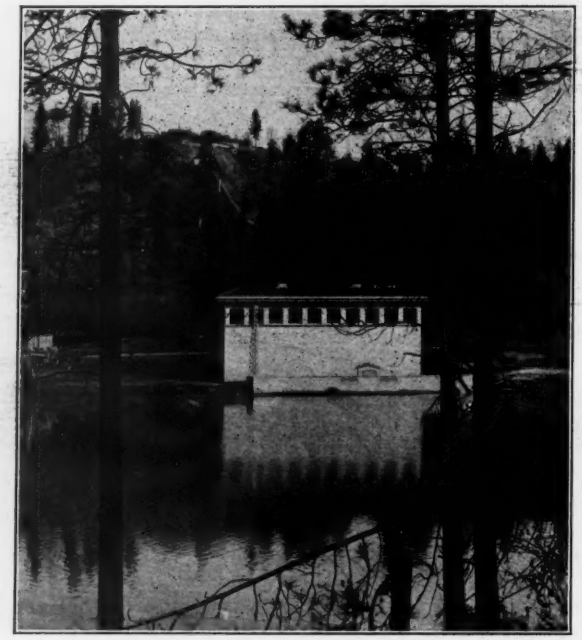


FIG. 1. HALSEY POWER HOUSE, CHARMINGLY SITUATED IN THE MOUNTAINS OF PLACER COUNTY, CAL., ADDS TO THE BEAUTY OF THE LANDSCAPE

of the station—certainly not enough to make any appreciable difference in the return to the stockholders. The Philadelphia Electric Co. has built other attractive stations, Delaware and Chester, and they do not seem to have suffered from any unusual burden of architectural expense. Chester Station, although an old plant and a comparatively small one as plants go today, remains one of the most magnificent power plant structures ever built. Both this station as well as Richmond were designed by John T. Windrim.

The views of Richmond Station shown here speak for themselves. The striking beauty of its structure is something that must impress even the most indifferent observer. It is located on the Delaware River adjacent to the line of the Pennsylvania Railroad between Atlantic City and Philadelphia, where it is seen by thousands of passengers daily. Surely, if public opinion is worth as much to the public service companies as they claim, the appearance of Richmond is an important asset to the Philadelphia Electric Co. for nothing will impress the public more favorably than the dignity and solidarity of Richmond Station.

Other recent stations of attractive appearance are Columbia of the Columbia Power Co., near Cincinnati, Crawford Avenue Station at Chicago, the Des Moines plant of the Illinois Power & Light Co., the Edgar Station at Boston and the East River Station in New York. Naturally, there are more, but these are representative types, each incorporating a type of architecture suited to its surroundings. None of them are spectacular or even elaborate, but their harmonious proportions and unbroken lines reflect a dignity which unconsciously commands the respect of the observer.

Whatever logical excuse there may be for ugliness in industrial power plant structures there can be no excuse for ugliness in central station structures. Industrial power plants are often located in places so drab, so utterly lacking in any attractive qualities that any amount of money or work spent on architectural embellishment would be lost. Central stations, because of their size and importance to the community which they serve, are rapidly becoming landmarks, points of interest to which visitors are directed and as such they should present an attractive appearance.

Attractiveness a Matter of Proper Co-Ordination Between Component Parts

While any attempt at beautification should be commended, very often well meant effort in this direction is brought to naught by improper handling or lack of co-ordination between component parts of a structure. Attention to the whole is of far greater importance than concentration on a few details. I have seen power stations decidedly unlovely and misproportioned but with elaborate entrances, extravagantly carved and fitted with artistic doors and grillwork. Considered alone such extrances were exceedingly attractive and a credit to the designer, but when regarded as a part of the plant as a whole, were little short of appearing ridiculous. It seemed as though the designer of the station, realizing the importance of his work too late, had added the elaborate doorway as an afterthought—a last minute effort to lend dignity to the sructure of which it was a part. Naturally, such doorways only accentuate the ugliness of the rest of the station by contrast. If the money so spent on mosaic entrances and bronze doors were applied to the cost of fitting the building with a simple stone cornice or in improving the general design of the building in any way, a far more satisfactory result would be secured.

There has been a tendency of late to incorporate the various divisions of a power plant in separate buildings with or without common dividing walls. However advisable this may be from an engineering or financial standpoint, it makes architectural treatment difficult. Where this plan of division is limited to the turbine room, boiler room and switchhouse, its effect upon the architecture is not serious and, if properly handled, can be made exceedingly attractive, as is seen in the design of Richmond. The tendency, however, is to carry the practice to extremes, the method of procedure apparently being to design the mechanical equipment and then to build the structure around it following the contour

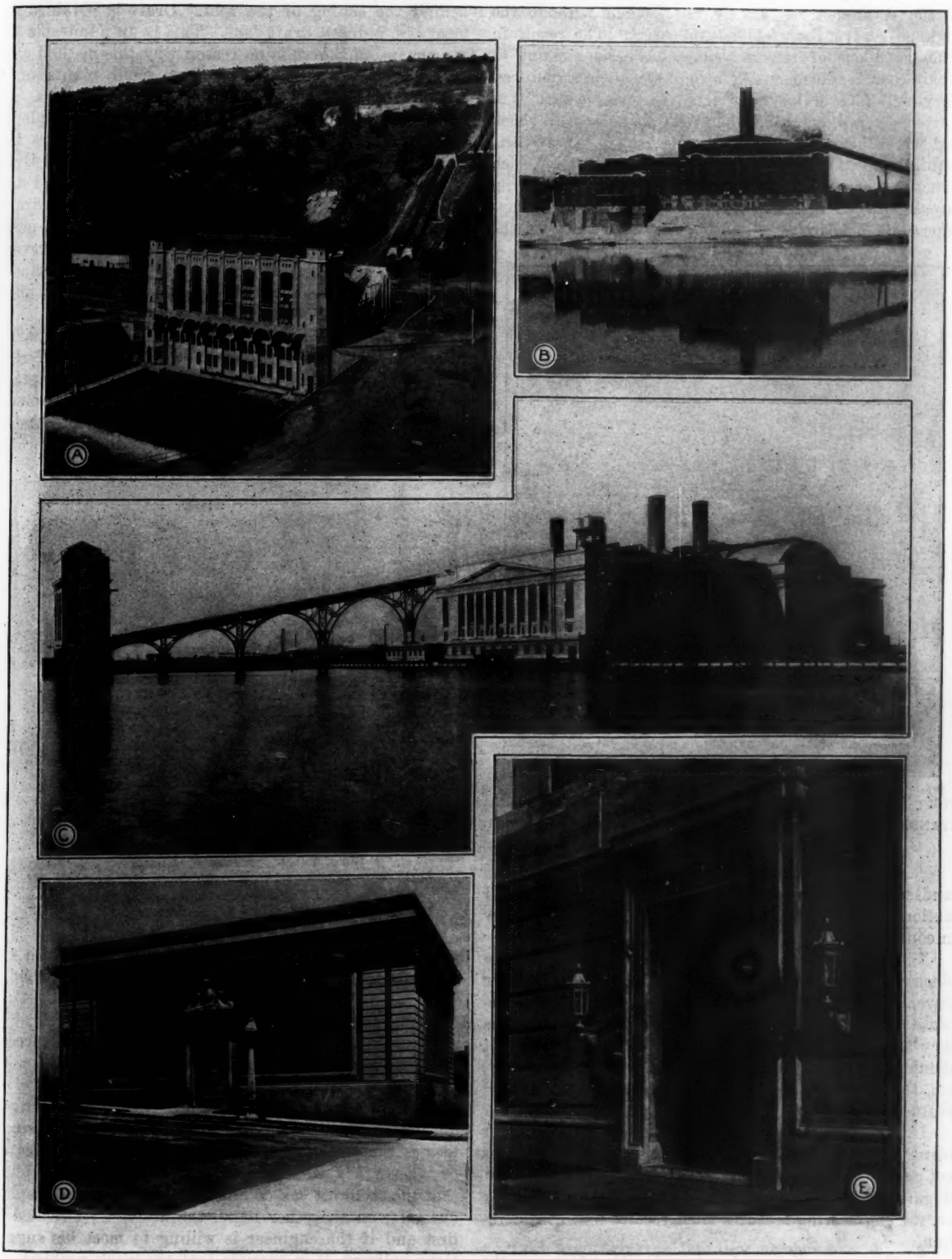


FIG. 2. SOME FINE EXAMPLES OF AMERICAN POWER PLANT STRUCTURES

A. An attractive hydroelectric station in Northern California, Pit River Power House No. 1. B. Columbia Power Station near Cincinnati is representative of a type of architecture used by Sargent & Lundy of Chicago. C. Richmond Station of the Philadelphia Electric Co. needs no comment. D. Station K, an attractive substation of the windowless type built by the Pacific Gas & Electric Co. at San Francisco. E. The simple dignity of this doorway at Richmond is in keeping with the architectural character of the station.

of the equipment as closely as possible without the slightest regard for architectural effect. The result in nine cases out of ten is abominable. No amount of architectural adornment can improve such structures. They will forever look like those factories which were started several generations ago with a single small shack and which have been added to, piece by piece, as their requirements for additional facilities increased. Such structures can never be dignified and the slight saving in cost effected by using such construction will always impose its burden as a liability on the beauty of the

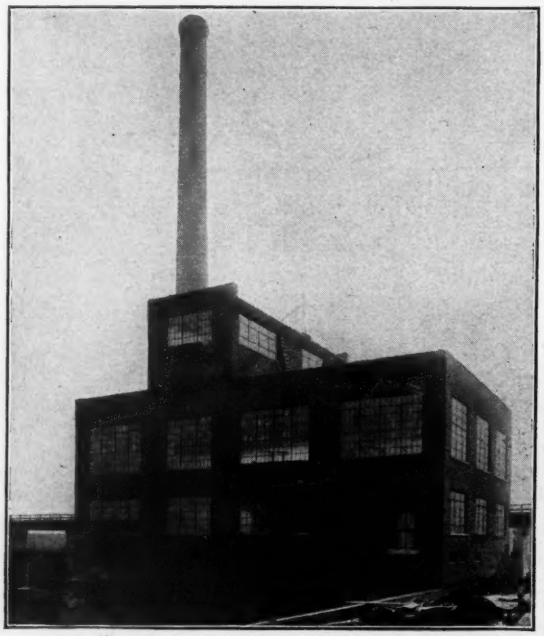


FIG. 3. HOWEVER EFFICIENT FROM AN ENGINEERING STANDPOINT, THIS INDUSTRIAL POWER PLANT IS DECIDEDLY UNLOVELY

landscape. Strange to relate, however, several central stations having this hodgepodge architecture are now in course of construction.

The fact that such structures are located in remote places away from the towns they serve is no excuse for slovenly architecture, in fact, the opposite is true. Because of their location away from all other structures they are likely to dominate the landscape and the effect should be pleasing rather than repulsive. Eventually, too, the town will grow up to the station.

SOME OF THE PROBLEMS CONFRONTING THE ARCHITECT

It is true that in designing the structure for a power plant the architect is somewhat handicapped. He does not enjoy the freedom that he has in designing a library. Regardless of how important architectural design may be, the engineering features must receive first consideration.

In this connection perhaps the limiting factor is the stack. So far no power plant utilizing fuel to raise steam in boilers has been able to dispense with the stack, that is, in the true engineering sense. In the case of the boiler house at Princeton University the stack has been dispensed with, so far as the eye is concerned, but its equivalent exists in a number of short thimbles hidden behind the coping of the roof. Draft is obtained by means of induced draft fans. This is an admirable arrangement and there is no reason why this method cannot be used in numberless other small plants of a similar nature.

While this plan is practical with small power plants it is not so well adapted to large stations where the quantity of flue gas to be discharged is enormous. Even where both forced and induced draft fans are used and the equipment is not dependent upon a stack for draft, short stacks must be provided to discharge the gases at a height sufficiently above the ground to prevent them from being obnoxious. Unfortunately, short stacks built along ordinary lines are as unsightly as tall ones, although perhaps not so conspicuous.

It is obviously a difficult problem but not necessarily hopeless. What is needed is an entirely different method of treatment, a method of concealing the stack that will at the same time harmonize with the general architectural lines of the building. Ornamental stacks have in certain instances been used with considerable

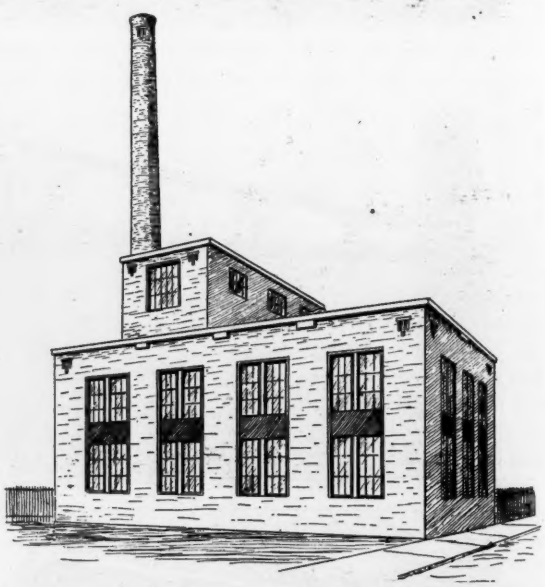


FIG. 4. BY SIMPLY ADDING A BIT OF STONE TRIMMING AND REDESIGNING THE WINDOWS, THE PLANT SHOWN IN FIG. 3 IS IMPROVED

success but it is evident that this cannot be as successful with central stations where there may be as many as a dozen stacks.

In this matter of stack design the architect is entirely dependent upon the mechanical layout. If the engineer locates the stacks wherever they will be most effective or where they will be least expensive, it is not likely that the architect can do much to make them inconspicuous. If, on the other hand, the architect, is called in first and if the engineer is willing to meet his suggestions halfway, it is possible that the stack problem can be made considerably less formidable than it usually is.

Stacks mounted directly on top of the building will be more conspicuous than stacks built at one end or at the sides of the building integral with the walls. In the latter case, an attractive buttress effect may be secured and if the upper portions are handled effectively

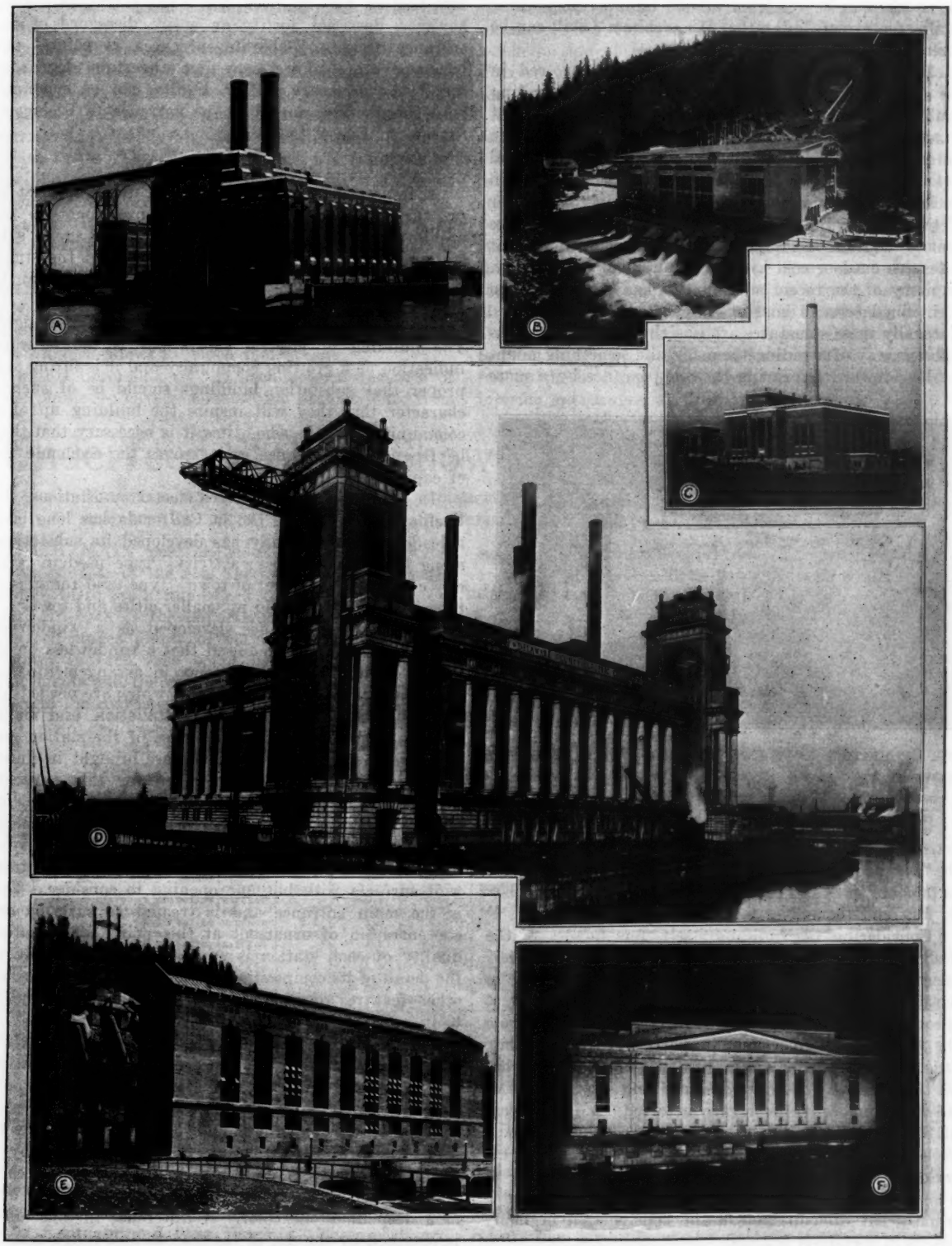


FIG. 5. MORE AMERICAN POWER PLANTS OF WHOSE ARCHITECTURE WE CAN BE PROUD

A. Edgar Station in Boston combines mass and simple beauty in an effective manner. B. Drum Power House, Placer County, Cal. C. Somerset Station of the Montaup Electric Co. is a typical Stone & Webster station of moderate capacity. D. Chester Station of the Philadelphia Electric, although an old station, remains one of the finest power plant structures ever erected. E. Another station of the Pacific Gas & Electric Co., Pit River No. 3. F. A flood lighted view of Richmond from a point across the Delaware river.

the stacks can be rendered almost unnoticeable. It is in this feature of design that the architect's skill can be demonstrated to greatest advantage.

Equally as difficult a problem as that involved in the design of the stack is that of the coal handling equipment. Here again it is the central station that is affected rather than the industrial plant. In the industrial plant where a relatively small amount of coal is to be handled, adequate facilities can be provided in bucket conveyors or skip hoists installed in the interior of the building but the amount of coal handled in large central stations assumes such huge proportions that extensive outdoor coal handling equipment is necessary. In many of the recent stations this has taken the form of inclined belts in housings supported on steel towers. Naturally these structures are unsightly but there seems to be no way of avoiding them. While something might be done toward improving their appearance by a more

FIG. 6. STATION K AT SAN FRANCISCO, UNDER THE SOFT GLOW OF THE FLOOD LIGHTS, IS A THING OF STARTLING BEAUTY

artistic design of the steel supporting towers, perhaps the best procedure is to make these structures as light as possible so as to render them less conspicuous. They do not lend themselves to beautification.

Considering the building itself, few factors in the design have as great a bearing on the general appearance as the design of the windows. Fortunately, in most power plants, the rooms are of a size sufficient to accommodate large windows which, when viewed from the exterior, are in correct proportion to the building. It is with the exterior appearance in mind, however, that all the windows should be designed and this means that when a number of floors are involved, as in the case of the switchhouse, the windows on these various floors should be combined so that when viewed from the exterior a vertical group will present the appearance of a single window. The accomplishment of this effect is usually not difficult, yet in the construction of many plants it is entirely ignored.

An essential difference between a large central station, and other large structures devoted to public service, is the fact that the public does not enter the building. A railroad terminal, a museum, or a library is constructed to accommodate large crowds, therefore they are designed with huge imposing entrances but a power station having a small personnel and relatively few visitors has no need for large entrances. This, however, does not justify an entire disregard of the entrance design. Elaborate entrances, as pointed out previously, are unnecessary but a certain degree of dignity is necessary. How dignity can be combined with simplicity is shown in the entrance to Richmond Station in Fig. 2.

Design of Substations

A few words about substations. During the past 10 yr. there has been a gratifying improvement in the architectural design of substations. Years ago a substation was considered a necessary evil and the structures were built with no other object in mind than to protect the equipment.

Today substations are regarded in a different light. The building of electric substations is the outward indication of a growing community and it is fitting and proper that substation buildings should be of such a character that they will inspire the building up of a community. At the same time it is necessary that they be free of extravagance and express the economic use of capital.

In the design of attractive electric substations, the Pacific Gas & Electric Co. in California has long been a leader. This company has developed its substations along two general types; a "city" type used in large city centers and an "out of town" type used for substations located outside and in smaller cities and towns.

The "city" type has developed as a windowless building, as it has been found that a windowless building gives the maximum economy in arrangement, that it provides unbroken wall surfaces which are needed for attaching various parts of the installation, and makes possible insulation against the noise of the station machinery. As all the power leads are brought in under ground, windows are not required for this purpose; nor are they needed for light and ventilation, since the interior is flooded with light from skylights and ventilation is best accomplished by forced draft.

This has given the designer an opportunity to treat wall surfaces with but one opening to consider. This is the main entrance and is treated as such by the concentration of ornament at this point. The individuality of each station is expressed architecturally in the detail of its composition and ornaments, also in such other features of its environment as may be peculiar to it.

A further distinction has been obtained in texture and color. Owing to the large flat wall surfaces without openings, uniformity in color and texture would have proved flat and uninteresting. This has been avoided by finishing the moulded members in a trowled sand finish and roughening the flat surfaces by a "scraping process." The color was obtained by a careful selection of the materials used and is a light buff or a deep limestone color. A difference in tone effect is obtained by the use of the smooth and rough texture and the whole is generally given a setting of smooth, well-kept lawn with groups of shrubbery placed to advantage.

For the "out of town" type of substation, an adaptation of the Spanish Renaissance style of architecture was developed because of its adaptability to the many exacting conditions and requirements of each station.

The early traditions of California had much to do with the selection of this style.

Somewhat the same conditions exist in these substations as in the city substations, except that in some cases the power leads come and go through windows which are necessarily placed with certain overhead clearance and thereby give large flat unbroken surfaces beneath them. This agrees well with the fundamental principles of Spanish Renaissance, i. e., the universal concentration of ornament at a few salient points.

This attitude towards the architectural design of their substations is also found in the design of the hydro-electric generating stations of the Pacific Gas & Electric Co. Although located at remote points hundreds of miles away from cities, these generating stations have been designed in keeping with the beautiful valleys and meadows in which they stand.

In this discussion of the architectural features of power plants we have considered the problem only from its broadest aspects. It is recognized that there is a distinct need for greater attention to the purely aesthetic side of power plant design and we have endeavored to direct attention only to the most glaring faults of present-day structures.

We are critical but at the same time, hopeful. The fact that such structures as those of Richmond, Columbia and Edgar are being built is encouraging. Progress in movements such as we are advocating is necessarily slow and we do not expect to transform all power plants into fairy palaces in five, ten or even fifty years' time. Existing stations cannot be dismantled merely because they are unattractive to the eye. They must live out their useful lives. Neither can we expect to design all new plants along the lines of the Parthenon or the Taj Mahal, but we can, and do expect, that the architectural design will be given at least as much consideration in the building of a station as is now accorded the interior appearance of the turbine room.

Underfeed Stokers Show Steady Improvement

MULTIPLE RETORT UNDERFEED STOKER SUCCESSFULLY ADAPTED TO COAL FROM ALL FIELDS AND FOR USE WITH WATER WALLS AND PREHEATED AIR. BY JOSEPH G. WORKER*

THREE MAIN coal fields in the United States supply most of the coal for steam boiler purposes, although there are a number of less extensive coal deposits. In each of the important coal fields there are underfeed stoker plants of major importance, the installation in each case being developed to meet the requirements and the characteristics of the various coal fields and the coal most available for use in the locality.

ciency and economical operation. The most important are Edgar, Hell Gate, Interborough, Kearny, Richmond, Chester, Bennings and Saxton. All of these plants are burning a grade of coal from Field 1 on multiple retort underfeed stokers.

Field 2 is located entirely in the state of Michigan. This coal is high volatile bituminous and is not considered a good steam coal. Average samples run about

TABLE I. STATIONS IN ALL PARTS OF THE COUNTRY ARE FIRED BY UNDERFEED STOKERS

Station		Hell Gate	Richmond	Saxton	Inter-borough	Chester	River-side	Saginaw	Neosho	Picway	Kearny
Boiler heating surface -	sq. ft.	12100	15692	11000	11400	14217	10440	9280	12000	14700	23600
Height of boiler -	tubes	12	Bent Tube	Bent Tube	24	Bent Tube	15	10	Bent Tube	18	20
Superheater size -	sq. ft.	4000	2822	1500	1485	2582	3014*	242'		3050	4130
% of boiler	surface	33	18	13.6	13	18.2	29.8	2.6		20.7	17.5
Economizer -	sq. ft.	10694	7515	6700	None	5850	6480	8500	3245	9655	None
% of boiler	surface	88.4	47.9	60.9		37	62	91.7	27	65.7	
Preheater size -	sq. ft.	None	22072	Bled	None	22000	Bled	Bled	Heated by	Bled	None
% of boiler	surface		140.5	Steam		154	Steam	Steam	Breeching	Steam	
Water cooled side walls-	sq. ft.	460	240	220	Air	None	Air	420	None	Air	Air
% of boiler	surface	3.8	1.6	2.0				4.5			
Rear wall cooling - proj. area	sq. ft.	None	355	204	Air	Air	57	83.5	52.0	94.0	Air
% of boiler	surface		2.2	1.85			0.54	0.9	0.43	0.64	
Proj. grate area -	sq. ft.	378	336.8	297.3	212	310	270.3	324	304.8	380.8	469.4
Boiler H.S. per sq. ft. of grate	sq. ft.	32	46.5	37	53.7	45.9	38.7	28.7	39.3	38.6	50.3
Width of stoker - No. of	retorts	14	15	11	7	15	10	12	12	12	16
Length of stoker - No. of	tuyeres	33	25	33	37	21	33	33	29	41	37
Combustion space above ash pit	cu. ft.	6500	7780	5200	3720	6650	5374	5520	6250	6000	10200

*Includes 89 sq. ft. of radiant superheater in rear wall
'Radiant superheater in rear wall

In the eastern portion of the United States the best coals are mined. These are semi-bituminous and bituminous, mostly high in carbon and having coking tendencies. They are excellent steam coals, containing about 14,500 B.t.u. per lb. and only 5 per cent ash. On the western border of this field are the coals of western Pennsylvania, eastern Ohio, a portion of the eastern part of Kentucky and West Virginia. These coals are bituminous and are partially coking coals, ranging from 5 to 18 per cent ash.

Along the Atlantic seaboard serving the big industrial regions of the country are a group of central stations notable for their progressive engineering, effi-

11,000 B.t.u. per lb. with about 14 per cent ash and 41 per cent volatile matter. The Saginaw River Station of the Consumers Power Co. with a very interesting installation of hydraulically driven underfeed stokers is designed to burn coal from either Field 1 or Field 2. This plant is now operating upon a coal from the state of West Virginia, Field 1, which averages about 13,000 B.t.u. The flexibility of the stoker installation permits the use of coal from any of these fields, whichever happens to be the most economical or convenient at the time.

In Columbus, O., just west of the limits of Field 1, is the recently completed Picway Station of the Columbus Ry. Power & Light Co. This plant is so situated that it can draw upon Fields 1, 2 or 3 for fuel supply

*Asst. to Pres., American Eng. Co., Philadelphia, Pa. Abstract of paper presented before Inst. of Eng. & Shipbuilders, Glasgow, Scotland, April 12, 1927.

and is equipped with a new design of stoker, which makes it possible to underfeed any of these coals with equal facility through extra long retorts. At Detroit, Mich., the new Beacon St. heating plant of The Detroit Edison Co. is of especial interest because the stokers were especially designed for this company with air-cooled side and front walls.

Coal from Field 3 in the state of Illinois, a portion of Indiana, and western Kentucky varies considerably. All, however, are bituminous, some being free-burning and some semi-coking with high ash content and low ash fusing temperatures. A great deal of this coal is burned at Riverside Station, a unit underfeed stoker station located on the Mississippi River between Fields 3 and 4, where fuel can be drawn from both sources.

TABLE II. COALS FROM THE VARIOUS FIELDS SHOW WIDELY VARYING CHARACTERISTICS

Station	Sulphur	Field	B.t.u. as Fired	Ash	Fixed Carbon	Volatile	Moisture
59th Street		1	14,149	6.75	74.30	15.75	3.20
Hell Gate	.77	1	14,010	7.16	70.19	18.85	3.80
Riverside	4.6	3	10,500	18		36	
	6.85	4	9,250	20		33	13
Picway		3	9,628	15	43.0	32	10
Richmond	.78	1	13,900	7.85	65.68	23.38	3.07
Neosho	4.25	4	10,976	15.0	45.5	28.3	11.2
Kearny		1	13,500	10.95	54.50	31.0	3.65
Chester	.94	1	13,890	7.43	70.00	19.30	3.27
Saginaw River	1.20	3	12,910	9.37	49.02	35.78	5.83
		3	13,298	8.0	50.0	36.9	5.1
Cedar Rapids	6.15	4	10,244	14.01	35.17	36.94	13.88
	5.03	4	11,027	16.00	45.02	30.74	8.24
	3.76	4	10,733	13.40	40.63	34.62	13.35
Norfolk	1.	1	14,550	6.	71.5	20.5	3.5

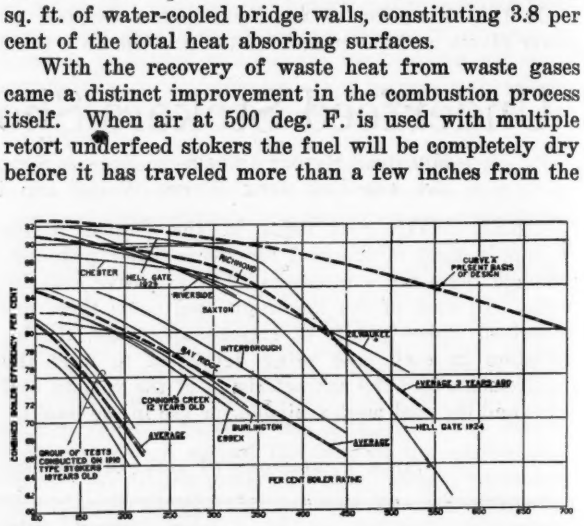
In addition to these three fields, Field 4 located in the states of Iowa, Missouri, Kansas and Oklahoma supplied a considerable quantity of the coal burned locally. Most of the coal in this field is low grade, high ash bituminous. The B.t.u. content runs about 11,500 per lb. for the best and 8500 B.t.u. per lb. for the poorer grade. Some of the poor Iowa coal contains 40 per cent ash, the ash in all of the coals fusing at a low temperature. In this field is the Neosho plant of the Kansas Gas & Elec. Co., where low grade Kansas and Oklahoma coals are burned in multiple retort underfeed stokers, in spite of the fact that both oil and gas compete with coal in that region.

In everyday commercial operation a variety of coking, non-coking, free-burning and lignite fuels is being handled, not only in the large central stations but in smaller power plants of industrial concerns. Two factors have operated to bring about the development of the stokers installed in the newer plants. One influence has been the desire to improve combustion conditions by better proportioning of stoker, boiler, economizer, preheater and other heat absorbing elements. The other influence has been the ever increasing size of boiler units. Big boilers demand the underfeeding of coal longer distances. With this lengthening of the retort there has been a development of the mechanism that controls the distribution of the coal along the stoker and its travel through the various combustion zones to the ashpit. Stokers are now underfeeding coal 18 ft. as compared to 6 or 7 ft. a few years ago.

Water cooling of furnace walls has increased capacity by making practical a heat release per cubic foot of furnace volume which would result in excessive temperatures if water-cooling were not used. Water-cooled walls are now used as often as air-cooled walls, especially where air-cooling is found to be insufficient for the rating required. At Hell Gate, for instance, the furnaces contain 460 sq. ft. of water-cooled side walls forming 3.8 per cent of the total boiler heating surface. At Saginaw 420 sq. ft. of water-cooled walls form 4.5 per cent of the boiler heating surface.

Success of water-cooled back walls combined with underfeed stokers quickly led to the extension of the system to the side walls; the furnaces at Saxton have 220 sq. ft. of water-cooled side walls and 204 sq. ft. of water-cooled back walls, constituting 3.85 per cent of the boiler surface. At the new Richmond Station there are 240 sq. ft. of water-cooled side walls and 355 sq. ft. of water-cooled bridge walls, constituting 3.8 per cent of the total heat absorbing surfaces.

With the recovery of waste heat from waste gases came a distinct improvement in the combustion process itself. When air at 500 deg. F. is used with multiple retort underfeed stokers the fuel will be completely dry before it has traveled more than a few inches from the front wall and the volatile constituents of the coal released at this point will be more completely consumed. The decrease in the space required for drying out the coal results in a corresponding lengthening of the zone on the stoker in which the fixed carbon is burned with a substantial increase in efficiency and capacity and a flattening of the load-efficiency curve. It has been found in practice that the use of preheated air reduces clinkering tendencies and assists in burning out traces of carbon from the ash.



TEST CURVES SHOW THE DEVELOPMENT OF BOILER AND STOKER PERFORMANCES DURING THE PAST 17 YR.

Richmond Uses Air Preheated to 350 deg. F.

Most of the pioneering in the use of highly preheated air in multiple retort underfeed stokers has been done by the Philadelphia Electric Co. at Chester Station. Data gained from experience with highly preheated air tests there were applied by the Philadelphia Electric Co. in the design of its Richmond Station at Philadelphia. Stoker design has been developed to meet the conditions brought about by preheated air and no difficulty has been experienced in using it at either Chester or Richmond. Neither have maintenance costs been increased.

Complete re-proportioning of the stoker for low

grade coals with rotary ash discharge to dispose automatically of the greater quantity of ash produced by the combustion of these coals has taken place and resulted in the redesign and re-proportioning of ashpits to accommodate the greater amount of discharge per unit of grate area. Deep ashpits not only accommodate larger quantities of ash but also give opportunity for the more complete burning of the combustible matter. Hydraulically-driven stokers provide a feed range which will operate the stoker at any capacity from 50 per cent to 700 per cent of rating and allow quick adjustments to meet changing fuel conditions.

Because of the necessary lag of two or three years between the design of the central station power plant and its going into operation, there is no existent plant data in which the full possibilities of the new multiple retort underfeed stoker, as its design has been developed today, are realized. The present 1927 multiple retort underfeed stoker will show performance in excess of anything yet attained and stokers are now being built for full automatic operation so that test results will be obtained in everyday practice. The new stoker is of such capacity that the boiler and not the stoker is the limiting factor in determining the size of the boiler furnace unit. Stokers sold for the new Saginaw River Station and for the first addition to the Edgar Station will underfeed coal to a longer retort than the 18-ft. ones at Pieway.

Results obtained with multiple retort underfeed stokers installed in recently completed steam stations in the United States are given here in curve form. A few of the most important stations have been selected, where tests have been conducted, and the results made known. Some of these plants are obtaining coal from Field 1 in the eastern part of the United States, others from Field 2 and Field 1, and still others use coal from Fields 2 and 3. Characteristics of the various coals are given in Table II and show, to a certain extent, the variation in the characteristics of coal from the various fields.

There seems to be no end to the multiple retort underfeed stoker development, nor has the ultimate development of the furnace around the stoker been reached. Developments which have taken place will be made more clear by referring to the efficiency curve herewith covering the trend in stoker, boiler and furnace efficiency for the past 17 yr. There is no attempt made to compare any of the particular boiler plants because they are using different kinds and types of boilers, different operating pressures, different ratios of heating surface of boilers and economizer surfaces; nevertheless they do show the average stoker and boiler operating efficiencies and capacities that have been obtained in different periods compared with what can be obtained today with all of the innovations being installed in connection with modern boiler room practice.

Rate Determinations Require Complete Analysis

THREE FUNDAMENTAL ELEMENTS ENTER INTO THE COST OF SERVICE; PRODUCTION COSTS, PROPER RETURN ON THE INVESTMENT AND JUST REWARD FOR BUSINESS ABILITY REQUIRED. THE RATE BASE IS OF PRIMARY IMPORTANCE. BY C. C. BROWN

ESTABLISHMENT of rates to be charged by a public utility for electric service is generally based primarily upon a reasonable return on the capital investment or rate base of that utility, which is used and useful and is essential to the rendering of such service to the public. Recognized charges which must be met by revenue derived under any rate schedule are operating expenses, taxes, depreciation and a fair return on the investment, which is usually taken as from 6 to 8 per cent of the rate base.

Actual determination of rate structure necessitates the determination of the average charge necessary per kilowatt-hour sold to meet the above charges, the blocking out of consumers and their demands and the determination of charges to be applied per kilowatt-hour sold in each block to produce the total revenue required. The charges or rates applied to the lower blocks are usually of higher rate than those applied to the larger blocks for the reason that the cost of serving the smaller consumers is much higher per kilowatt-hour sold than that of serving the larger consumer.

Such a schedule is shown graphically in Fig. 1. Domestic heating and lighting is covered by two schedules and general power service by a third. In each case a minimum charge is made based either on the number of meters or the connected load. Direct current charges

TABLE I. ANALYSIS OF UNIT COSTS SHOW RELATIVE IMPORTANCE TO EACH ITEM

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1924*
UNIT COSTS PER KW-HR. SOLD													
Production	.0161	.0154	.0152	.0144	.0137	.0149	.0172	.0200	.0196	.0117	.0068	.0058	.0063
Distribution	.0064	.0059	.0058	.0057	.0060	.0050	.0036	.0034	.0037	.0033	.0032	.0022	.0036
Commercial	.0029	.0028	.0027	.0027	.0036	.0038	.0028	.0022	.0020	.0019	.0019	.0013	.0023
General	.0022	.0019	.0018	.0020	.0030	.0021	.0020	.0014	.0014	.0015	.0013	.0009	.0015
Other Expense	—	—	—	—	—	—	.0003	.0002	.0003	—	—	—	—
Taxes	.0026	.0026	.0027	.0026	.0029	.0031	.0038	.0027	.0035	.0039	.0040	.0024	.0035
Depreciation	.0115	.0110	.0094	.0089	.0088	.0048	.0043	.0032	.0029	.0027	.0026	.0017	.0027
Total	.0417	.0396	.0376	.0363	.0380	.0337	.0340	.0331	.0334	.0250	.0198	.0143	.0199
GROSS UNIT REVENUE PER KW-HR. SOLD	.0579	.0547	.0537	.0527	.0490	.0468	.0460	.0437	.0456	.0398	.0371	.0264	.0372
NET " " " " "	.0162	.0151	.0161	.0164	.0110	.0131	.0120	.0106	.0122	.0148	.0173	.0121	.0173
TOTAL ELECTRIC EMPLOYEES	248	259	260	263	284	223	227	351	380	645	994	1,418	1,418
OVERHEAD DISTRIBUTION													
Primary - Miles	1,409	1,580	1,612	1,678	1,676	1,690	1,729	1,785	784	871	977	1,010	1,010
Secondary "	944	1,027	1,070	1,114	1,113	1,122	1,147	1,185					
UNDERGROUND DISTRIBUTION													
Duct - Miles	128	129	129	129	133	133	134	134	144	144	168	173	173
Cable "	171	180	186	193	194	195	190	194	206	221	242	251	251

*Excluding Cost and Sale of Power sold wholesale

TABLE II. DETERMINATION OF THE RATE BASE IS OF PRIMARY IMPORTANCE FOR DETERMINING THE RATE SCHEDULE

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1924*	1925
FIXED CAPITAL TANGIBLE														
A. Prior to Jan. 1, 1913	5,046,316.22	4,982,856.05	4,922,360.07	4,859,671.24	4,749,650.19	4,717,047.36	4,676,172.37	4,643,457.43	4,511,510.54	4,250,901.53	4,091,122.04	4,009,925.18	4,009,925.18	3,908,681.18
B. Since Dec. 31, 1912														
Land	1,428.80	2,628.95	4,123.55	4,123.55	5,759.40	5,759.40	5,759.40	5,759.46	141,303.40	232,678.97	333,790.82	--	--	--
Production	66,349.16	87,376.27	120,325.52	191,127.61	223,327.07	226,327.66	226,384.16	399,597.32	1,261,975.62	2,728,453.92	4,139,832.12	7,100,901.06	7,100,901.06	9,555,107.06
Transmission	--	--	--	--	--	--	--	--	--	--	--	1,179,203.58	1,179,203.58	2,067,717.58
Distribution	280,649.67	599,246.30	776,943.51	988,187.33	1,263,366.10	1,370,170.06	1,491,515.93	1,785,623.15	2,506,768.28	3,450,569.83	5,463,542.02	8,752,826.16	8,752,826.16	12,300,247.16
Utilization	--	--	--	--	--	--	--	--	--	--	--	281,289.59	281,289.59	281,289.59
General	6,469.59	13,572.74	18,977.70	25,203.02	31,482.32	32,062.60	26,669.72	38,183.99	90,010.22	161,292.74	291,761.23	1,087,036.17	1,087,036.17	1,133,801.17
Total	354,887.22	702,824.26	920,370.28	1,198,641.51	1,523,934.89	1,634,319.72	1,750,328.21	2,229,163.86	4,000,057.52	6,572,995.46	10,228,926.19	18,401,256.56	18,401,256.56	25,338,162.56
Total Tangible	5,401,203.44	5,685,680.31	5,842,730.35	6,058,312.75	6,273,585.08	6,351,367.08	6,426,500.58	6,872,621.29	8,511,568.06	10,823,896.99	14,320,048.23	22,411,181.74	22,411,181.74	29,246,843.74
FIXED CAPITAL INTANGIBLE	--	--	--	--	--	--	--	--	13,472.01	30,090.57	36,057.96	124,169.06	124,169.06	189,169.06
TOTAL FIXED CAPITAL AS OF DEC. 31	5,401,203.44	5,685,680.31	5,842,730.35	6,058,312.75	6,273,585.08	6,351,367.08	6,426,500.58	6,872,621.29	8,525,040.07	10,853,987.56	14,356,106.19	22,535,350.80	22,535,350.80	29,436,012.80
RATE BASE														
Average FIXED CAPITAL as of JUNE30	5,223,759.83	5,543,441.87	5,764,205.33	5,950,521.55	6,165,948.92	6,312,476.08	6,388,933.83	6,649,560.94	7,698,094.68	9,667,732.53	12,571,972.61	18,365,614.99	18,365,614.99	25,829,012.74
Working cash capital	124,115.25	139,039.80	136,088.18	142,899.82	153,284.38	117,908.40	116,062.98	161,642.41	176,412.52	153,352.78	140,505.19	219,076.34	187,238.06	203,204.17
Materials and supplies	115,750.00	144,200.00	149,900.00	154,700.00	160,400.00	164,000.00	166,200.00	172,900.00	200,200.00	252,000.00	328,000.00	476,013.00	476,013.00	675,500.00
Total rate base	5,463,625.08	5,826,681.67	6,050,163.51	6,247,611.37	6,479,633.30	6,594,384.48	6,671,196.81	6,984,103.35	8,068,707.20	10,073,085.31	13,040,477.80	19,060,704.33	19,028,866.05	26,707,716.91
AVERAGE FIXED CAPITAL PER CONSUMER	144.70	147.40	141.50	138.70	145.80	154.90	152.60	147.00	149.40	156.00	159.40	184.30	184.30	223.20
DEPRECIATION RESERVE	788,295.82	1,057,928.23	1,289,137.79	1,530,341.89	1,762,523.17	1,964,919.51	2,172,753.31	2,400,733.54	2,320,232.29	2,338,707.07	2,462,888.61	2,774,226.06	2,774,226.06	3,224,226.06
TOTAL OPERATING REVENUE	1,438,857.85	1,495,979.63	1,560,039.85	1,665,882.15	1,628,214.43	1,485,814.43	1,650,484.97	2,135,655.83	2,787,335.72	3,183,925.52	3,926,340.59	5,719,484.67	4,847,331.37	5,813,156.00
OPERATING EXPENSE														
Production	399,744.90	422,794.90	441,014.57	454,294.25	456,756.93	472,087.04	615,630.19	981,692.21	1,197,182.28	941,119.61	722,493.16	1,252,245.88	821,214.88	1,061,250.00
Distribution	158,466.29	160,498.96	166,155.42	180,842.41	197,863.42	158,761.03	130,250.24	166,434.80	224,235.59	263,063.14	341,157.72	473,062.22	473,062.22	520,000.00
Commercial	73,161.58	77,846.92	79,064.09	86,000.92	122,117.77	122,150.09	99,426.50	107,060.32	123,593.55	152,543.37	198,042.98	277,370.79	277,370.79	319,000.00
General	55,107.64	52,842.16	53,605.55	63,074.46	98,937.98	68,013.18	72,732.32	67,927.74	84,844.09	119,118.22	142,672.60	187,882.41	187,882.41	216,000.00
Other Expense	--	--	--	--	--	--	9,720.97	9,140.81	17,187.61	--	--	--	--	--
Taxes	63,991.72	67,478.02	78,268.48	81,915.92	96,999.58	98,264.03	137,941.69	130,797.18	214,183.44	308,906.04	418,375.22	528,588.63	473,448.63	665,000.00
Depreciation Annuity	286,091.93	302,079.01	272,879.61	281,532.50	292,337.22	150,621.28	152,732.44	157,537.89	177,910.25	214,913.79	274,549.49	361,829.38	361,829.38	450,000.00
Total	1,036,564.06	1,083,539.97	1,092,987.72	1,147,660.46	1,265,012.91	1,069,906.65	1,218,434.35	1,620,590.95	2,039,136.81	1,999,664.17	2,097,291.17	3,080,979.31	2,594,808.31	3,231,250.00
NET OPERATING REVENUE	402,293.79	412,439.66	467,052.13	507,921.69	363,201.52	415,907.78	432,050.62	515,064.88	748,198.91	1,184,261.35	1,829,049.42	2,638,505.36	2,252,523.06	2,581,906.00
PER CENT RETURN	7.32	7.06	7.72	8.13	5.61	6.31	6.48	7.37	9.27	11.76	14.02	13.84	11.83	9.67

*Excluding Cost and Sale of Power sold wholesale

TABLE III. COMMERCIAL LIGHTING AND POWER CONSTITUTE THE MAJOR PORTION OF THE LOAD

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1924*
PLANT CAPACITY KW.	23,552	23,552	23,552	23,552	23,102	22,877	22,877	19,710	29,210	42,400	56,200	71,000	71,000
YEARLY OUTPUT KW-HR.	31,457,345	34,443,927	36,381,712	40,169,737	42,152,000	41,010,000	40,714,000	57,626,627	74,064,781	92,940,459	126,691,871	244,926,177	158,719,977
YEARLY PEAK KW.	11,590	12,740	13,099	13,620	13,310	13,260	15,404	17,785	26,136	32,100	43,500	69,000	54,500
YEARLY LOAD FACTOR %	30.9	30.9	31.7	33.7	36.2	35.3	30.2	37.0	32.4	33.1	33.2	40.5	33.3
PURCHASED CURRENT KW-HR.	No record	No record	No record	No record	No record	1,992,000	3,313,000	1,995,556	1,842,945	811,933	665,330	121,253	121,253
CONNECTED LOAD KW.													
Lighting Commercial	34,179	38,054	41,773	43,660	41,656	41,183	44,079	47,731	59,303	73,605	98,409	127,895	127,895
" Municipal Street	442	462	508	565	346	364	300	313	339	351	359	434	434
" " Other	--	--	--	--	194	165	152	167	168	134	130	139	139
Power Commercial	12,783	14,229	14,399	15,222	15,408	15,189	18,049	20,839	27,128	38,802	48,908	67,960	67,960
" Municipal	115	111	258	319	109	76	44	50	44	70	59	71	71
Total Connected Load	47,519	52,856	56,938	59,766	57,713	56,926	62,624	69,094	86,988	112,962	147,865	196,499	196,499
CONSUMERS INDEPENDENT METERS													
Lighting Commercial	34,667	37,619	40,359	41,978	38,983	38,621	40,868	44,833	52,568	64,856	85,126	105,609	105,609
" Municipal Street	94	96	106	118	57	63	50	52	55	59	65	68	68
" " Other	--	--	--	--	55	48	47	51	52	50	71	79	79
Power Commercial	1,315	1,444	1,519	1,659	1,765	1,898	2,125	2,444	3,014	3,599	4,373	5,308	5,307
" Municipal	10	11	15	18	9	8	6	6	8	8	8	11	11
Total Meters	36,086	39,170	41,999	43,773	40,869	40,638	43,096	47,386	55,697	68,572	89,643	111,075	111,074
Average Meters	36,086	37,628	40,584	42,886	42,321	40,754	41,867	45,241	51,541	62,134	79,108	100,359	100,359
CLASSIFIED SALES KW-HR.													
Lighting Commercial	16,637,825	18,653,618	19,884,269	21,621,084	22,509,000	20,618,000	23,380,000	30,487,561	38,321,368	48,641,560	65,140,334	80,621,742	80,621,742
" Municipal Street	613,172	786,998	805,883	1,010,477	862,000	799,000	799,000	745,229	754,784	929,521	977,077	1,017,090	1,017,090
" " Other	--	--	--	--	167,000	91,000	83,000	97,998	125,601	131,752	105,927	157,092	157,092
Power Commercial	7,587,289	7,884,913	8,291,285	8,841,833	9,635,000	10,195,000	11,565,000	16,900,778	21,917,587	30,440,078	39,439,451	48,316,238	48,316,238
" Municipal	42,610	50,661	74,936	131,803	85,000	27,000	19,000	20,290	21,017	25,337	74,156	34,938	34,938
" Resale to other Corporations	--	--	--	--	--	--	--	663,600	--	--	80,414	86,206,200	--
Total Sales	24,880,896	27,376,190	29,056,373	31,605,197	33,258,000	31,730,000	35,846,000	48,915,456	61,140,357	80,168,248	105,817,359	216,353,300	130,147,100
SALES FOR INDEPENDENT METER KW-HR.	689	699	692	722	814	781	832	1,032	1,097	1,168	1,180	1,948	1,171

*Excluding Cost and Sale of Power sold wholesale

FIG. [illegible] THOUSANDS, KW. MILLION K.W.HR. RATE CENTS PER K.W.HR.

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are made at an increase of 20 per cent over alternating current rates and for general power service an off peak rate 20 per cent less than the regular schedule is offered for the periods from 9:30 p. m. to 4:30 p. m.

This schedule is for the electric division of a western gas and electric utility serving a large portion of a rapidly growing city. Consumers are fairly concentrated and long transmission of power is unnecessary. The division of the underground and overhead distribution system is given by Table I and shows a rapid increase in in the underground system.

Growth of the company from 1913 is represented in Fig. 2. Transmission and distribution losses are shown by the difference between the total plant output and the total sales which are made up largely of commercial lighting and power. Distribution of these sales into five classifications are given in detail in Table III.

This table also gives the distribution of the connected load and meters between the various classes of service. The connected load ranges from 10,000 to 15,000 kw. higher than the plant capacity which is, in

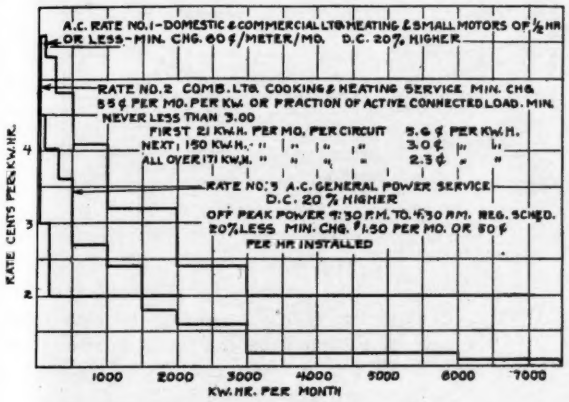

A.C. RATE NO.1-DOMESTIC & COMMERCIAL LTG. HEATING & SMALL MOTORS OF ½ HP OR LESS-MIN. CHG. 60 ¢/METER/MO. D.C. 20% HIGHER
RATE NO.2 COMB. LTG. COOKING & HEATING SERVICE MIN. CHG. 85 ¢ PER MO. PER KW. OR FRACTION OF ACTIVE CONNECTED LOAD. MIN. NEVER LESS THAN 3.00
FIRST 21 KW.H. PER MO. PER CIRCUIT 5.6 ¢ PER KW.H.
NEXT 150 KW.H. " " " 3.0 ¢ " "
ALL OVER 171 KW.H. " " " 2.3 ¢ " "
RATE NO.3 A.C. GENERAL POWER SERVICE D.C. 20% HIGHER
OFF PEAK POWER 9:30 P.M. TO 4:30 A.M. REG. SCHED. 20% LESS MIN. CHG. $1.50 PER MO. OR 50 ¢ PER HP. INSTALLED
RATE CENTS PER KW.HR.
KW.HR. PER MONTH

FIG. 1. THREE RATE SCHEDULES ARE IN USE

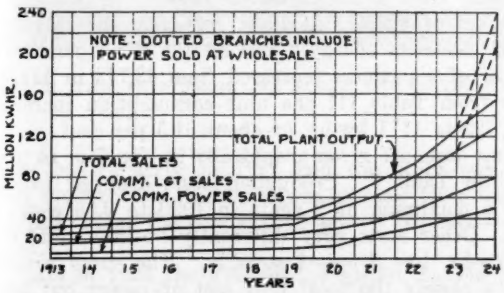


FIG. 2. DISTRIBUTION LOSSES ARE SHOWN BY THE DIFFERENCE BETWEEN THE OUTPUT AND SALES

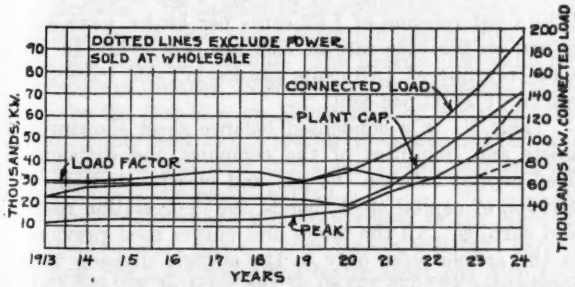


FIG. 3. PLANT CAPACITY HAS KEPT PACE WITH THE CONNECTED LOAD

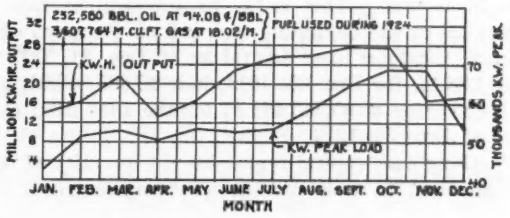

232,500 BBL. OIL AT 94.08 ¢/BBL.
3,607,764 M.CU.FT. GAS AT 18.02/M.
FUEL USED DURING 1924
KW.H. OUTPUT
KW. PEAK LOAD
MILLION KW.HR. OUTPUT
THOUSANDS KW. PEAK
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
MONTH

FIG. 4. PEAK LOADS OCCUR IN THE FALL

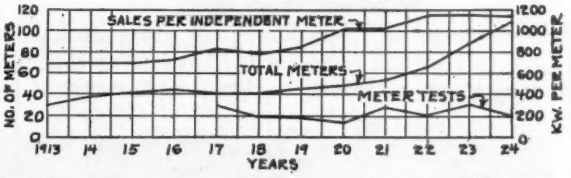


FIG. 5. SALES HAVE INCREASED TO ALMOST 1200 KW-HR. PER METER

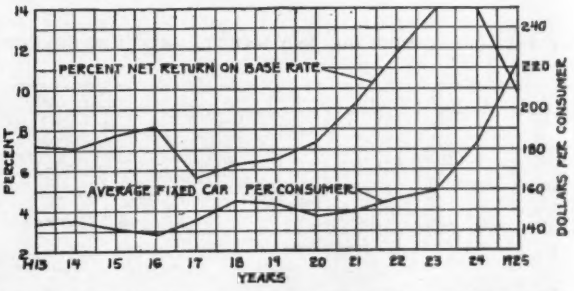


FIG. 6. FIXED CAPITAL PER CONSUMER HAS ALMOST DOUBLED SINCE 1920

turn, kept about the same margin over the yearly peak as shown graphically in Fig. 3. The yearly load factor is between 30 and 40 per cent while variation of the plant output and peak throughout the year, plotted by months on Fig. 4, show that the heaviest loads occur in the late summer and early fall.

Total meters installed and the number of meter tests each year are shown on Fig. 5, together with the sales per meter which have increased from 689 kw-hr. per meter in 1913 to almost 1180 in 1923. An analysis of all meter tests shows that the major portion of all meters tested is within plus or minus 2 per cent of being accurate and of the more inaccurate ones the tendency is to read slow.

Accidents to both employes and public are also shown in Table II. In 1923 there were no fatalities; in 1924 there were three, two of them employes. In 1923, seventy-three property accidents resulted in a loss of $4,472.69 and in 1924 this loss had increased to $13,352.10, resulting from 129 accidents. The total number of employes and the salaries paid during 1923 are given in Table IV. Fuel costs included in Table IV cover fuel oil, 42 gal. per bbl., testing approximately 18,600 B.t.u. per bbl., and natural gas with a heating value of 1200 B.t.u. per cu. ft., 5600 cu. ft. of gas being considered equivalent to approximately 1 bbl. of fuel oil.

Capital investment, made up of tangible, intangible and working cash capital and materials and supplies, is given in detail in Table III with the tangible capital segregated under six subdivisions. For the determination of the base rate the average fixed capital as of

June 30 is used. This is the arithmetical average of the capital at the beginning and end of the year. For instance, the total fixed capital as of Dec. 31, 1913, is $5,401,203.44, for Dec. 31, 1914, it is $5,685,680.31, giving the average of $5,543,441.87 for the 1914 fixed capital as of June 30, 1914.

Working cash capital represents the quantity of cash kept on hand to meet current operating expenses. In this company it is made up by adding to 1 mo. fuel costs, 2 mo. operating expenses less fuel costs and taxes, and subtracting one-quarter of the annual taxes. In 1925 the working cash capital was from Table III $203,204.17 made up as follows: From Table V fuel costs totaled $699,050,000, an average of $58,254.17 per month. Total operating expense for the year was $3,231,250.00. Subtracting from this $665,000 for taxes and $699,050 for fuel and dividing the balance by six gives $311,200 for 2 mo. operation. One-quarter of the total taxes, $665,000, is $166,250. Adding $58,254.17, $311,200.00, and subtracting $166,250.00 gives a value of $203,204.17 for the working cash capital.

In addition to the average base rate and operating expense, Table II lists the yearly gross revenue, yearly net revenue, accrued depreciation and percentage return or net revenue on the rate base resulting from the rates in effect during these years. During this period the total fixed capital increased from $5,401,203.44 to $29,406,012.80 and the rate base increased from $5,493,625.08 to $26,707,716.91, increases of about 545 and 486 per cent respectively.

TABLE IV. EMPLOYES ARE DIVIDED BETWEEN THE VARIOUS DEPARTMENTS AS SHOWN

	Number on Dec. 31, 1923-Dec. 31, 1924		Total Salaries and Wages Paid in 1924
EMPLOYEES IN			
General Officers	5-50/100	7-1/3	$ 48,277.79
General Office	140	166-25/100	275,734.97
Branch "	9-75/100	14-75/100	23,190.32
Total Office Force	155-25/100	188-1/3	347,203.08
EMPLOYEES IN			
Production System	120	136	263,285.07
Transmission "	-	-	--
Substations	15	18	37,051.70
Distribution "	94	163	333,811.93
All Other	609-50/100	913	1,046,634.39
Total	993-75/100	1,418-1/3	$ 2,027,986.17

TABLE V. BOTH FUEL OIL AND NATURAL GAS ARE BURNED

	OIL			NATURAL GAS			
Year	Barrels	Av. Cost	Amount	M.Cu.Ft.	Av. Cost	Amount	Total
1913	146,300	$.67	$98,421.11	380,574	$.12	$45,365.42	$143,786.53
1914	67,663	.65	44,250.58	805,285	.14	114,961.64	159,212.22
1915	25,333	.65	16,519.87	1,038,679	.14	145,415.06	161,934.93
1916	18,402	.60	11,012.67	1,194,649	.14	167,250.86	178,263.53
1917	38,780	.66	25,679.45	1,236,878	.145	179,935.92	205,615.37
1918	78,619	1.22	95,690.59	929,439	.148	137,901.83	233,592.42
1919	179,904	1.57	281,857.90	486,919	.149	72,546.98	354,404.88
1920	380,238	1.64	623,568.54	113,672	.210	22,918.64	647,487.18
1921	376,408	1.77	667,413.31	404,058	.255	102,992.92	770,406.23
1922	443,563	1.25	554,686.90	324,904	.184	59,877.89	614,564.79
1923	143,098	.85	121,633.47	2,082,425	.142	295,010.41	416,643.88
1924	252,580	.94	237,628.74	3,607,764	.180	650,470.53	888,099.27
1925*	250,000	1.50	375,000.00	2,160,335	.15	324,050.00	699,050.00

*Estimated

TABLE VI. A CONDENSED BALANCE SHEET FOR JAN. 1, 1925

ASSETS		
Fixed Capital - Gas	$49,524,079.70	
Electric	22,535,350.80	$72,059,430.50
Subscribers to Capital Stock		708,814.91
Sinking Funds		1,246,438.47
Materials and Supplies - Gas	1,352,895.11	
Electric	476,012.85	1,828,907.96
Cash and Deposits		3,770,159.23
Miscellaneous Assets		2,201,367.25
Deferred Charges		3,379,129.98
Total		$85,194,248.30
LIABILITIES		
Capital Stock:		
Preferred (incl. subs.)	$14,139,280	
Common	12,500,000	26,639,280.00
Bonds (less Treasury Securities $1,445,000)		43,314,500.00
Miscellaneous Liabilities		4,958,007.78
Depreciation Reserve - Gas	5,218,355.34	
Electric	2,761,470.60	7,979,825.94
Surplus		2,302,634.58
Total		$85,194,248.30

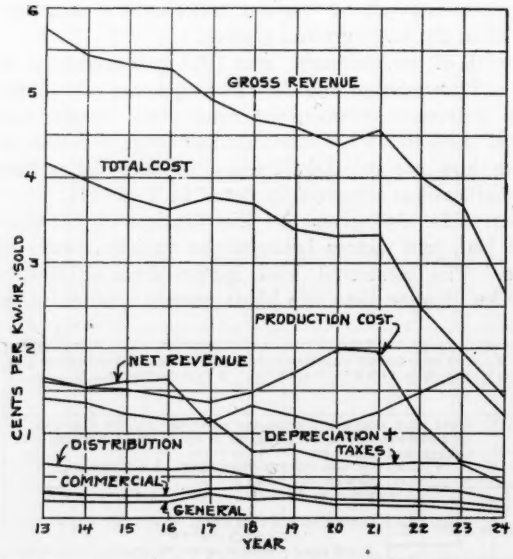


FIG. 7. PRODUCTION COSTS WERE CUT 75 PER CENT IN THREE YEARS

Operating expenses varied according to conditions so that the rate of return ranged from a minimum of 5.61 per cent in 1917 to a maximum of 14.02 per cent in 1923. This is shown graphically in Fig. 6, together with the average fixed capital per consumer. The latter increased from a minimum of $138.70 in 1916 to a maximum of $223.20 in 1925, reflecting the increased use of electrical energy. During the same period the number of consumers increased from 43,773 to 111,074 while from Table III the unit consumption increased from 722 to 1171 kw-hr. or about 61.5 per cent.

Unit costs are given graphically in Fig. 7 or in more detail in Table I. Production costs dropped rapidly from a maximum of 2 cents in 1920 to 0.58 cents in 1924. Other costs vary differently but the total cost per kw-hr. has dropped steadily. The gross revenue follows closely the total unit cost of power but bears no resemblance to the net revenue per unit of power sold. It is interesting to compare Figs. 6 and 7. In 1913 a net revenue of 1.62 cents per kw-hr. gave a net return on the base rate of 7.32 per cent, while in 1923 a net revenue of 1.73 cents per kw-hr. sold gave a net return of 14.02 per cent.

Table VI is a condensed balance sheet showing the assets and liabilities of the company, the division of fixed capital between the gas and electric division, the division of capital stock, bonds, the depreciation reserve and surplus. All the tables and curves used previously in the article refer only to the electric division which constitutes $22,535,350.80 of the total of $72,059,430.50 fixed capital.

Trenton Channel Plant Nears Ultimate Capacity

UNITS 4 AND 5 IN DETROIT EDISON CO.'S PLANT NOW IN OPERATION, UNIT NO. 6, AND LAST, UNDER CONSTRUCTION. IMPORTANT CHANGES MADE IN GENERATORS, CONDENSERS, BOILER FEED PUMPING AND PRECIPITATORS. BY CHARLES M. DRAKE*

IN THE Detroit district, the load has increased so much more rapidly than was anticipated when Trenton Channel was first built and put into commission that it has been necessary to add to the capacity of the plant sooner than was originally planned. The first section of the plant was completed in January, 1925, with three turbines and eight boilers in operation. At that time the plan was to add the fourth unit with three boilers early in 1927 and the other two units with their corresponding boilers at some later date depending upon the amount of power required of the plant.

Late in 1925 the load on the system had increased so much that it became apparent it would be necessary to change the construction schedule to meet the increasing demand. Consequently two turbines were ordered for delivery in 1926 and a third for late in 1927. This plan has been carried out. The fourth unit went into operation in October, 1926 and the fifth unit was turned over for the first time on February 8 of this year. The building has been completed for the sixth and last unit which will be delivered at the end of the year and will go into operation early in 1928.

Three boilers have just been added to the eight already installed. These eleven boilers will take care of the first five machines. The boiler room has been completed with an additional bay for a battery of three boilers the first one of which will probably be installed in the fall of 1928 after the sixth turbine is built.

NEW EQUIPMENT PRACTICALLY DUPLICATE OF THAT FIRST INSTALLED

In designing the new section, the scheme followed out was to have the new machines as nearly as possible duplicates of the machines installed in the first section.

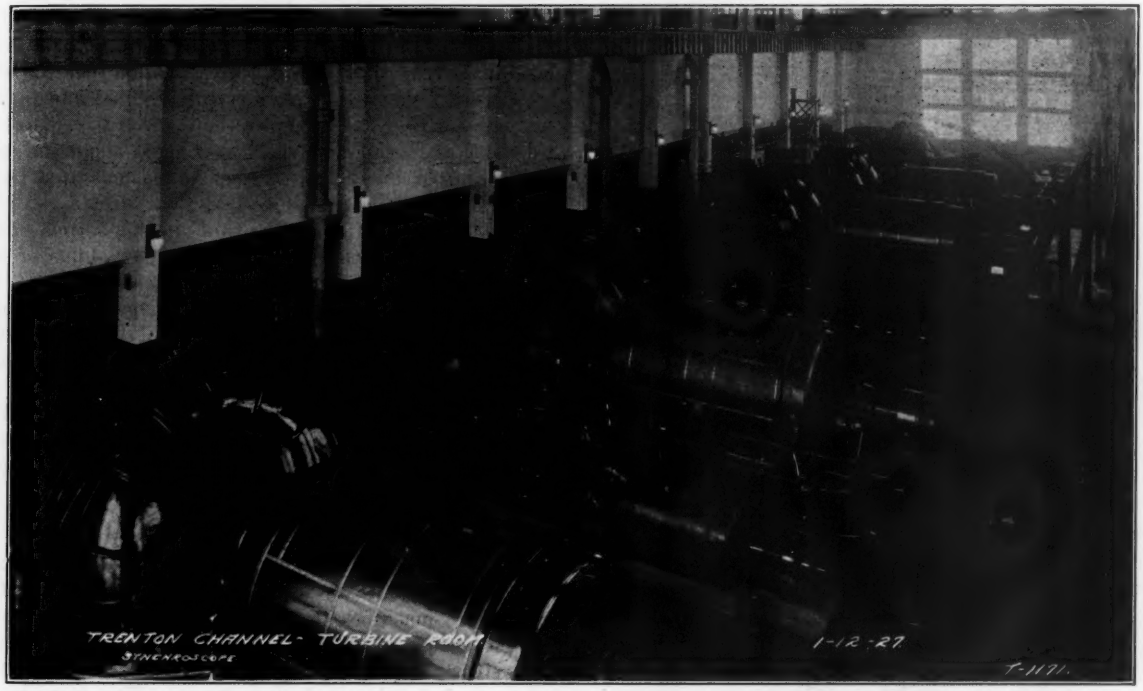


FIG. 1. THIS VIEW FROM THE NORTH END OF THE TRENTON CHANNEL TURBINE ROOM SHOWS THE FIFTH UNIT UNDER CONSTRUCTION

This simplifies the operation of the plant considerably because an operator familiar with one machine can take care of any similar machine throughout the plant with the least possibility of his making a mistake due to machines of different design being used for the same type of service. Another advantage gained by using duplicate equipment is that a proportionately smaller number of spare parts are carried for the whole plant than would be the case if the machines were not duplicates. In case of serious difficulties the parts of one machine are interchangeable with those of another.

Some changes, however, have been made. These were made only after it had been definitely determined that the existing equipment was not working as well as had been anticipated when it was originally installed. All changes that have been made were planned in such a way that if it should prove desirable the equipment already installed in the first section of the plant could be changed at the least possible expense to make it duplicate to that in the new section.

*Engineer, Detroit Edison Co.

Ventilation of Generator Improved

The steam ends of the units are practically duplicates of the old machines but the generators have been changed somewhat. The fields have been made more rugged and the ventilation has been improved so that it is possible to maintain a higher field current on the new units than it was on the old with less heating of the coils. The last generators have the same overall dimensions as the first and the rotors are interchangeable, although a rotor from the first machines, if operated in a new stator, would prove a limiting factor in the capacity of the machine. The new type of coils

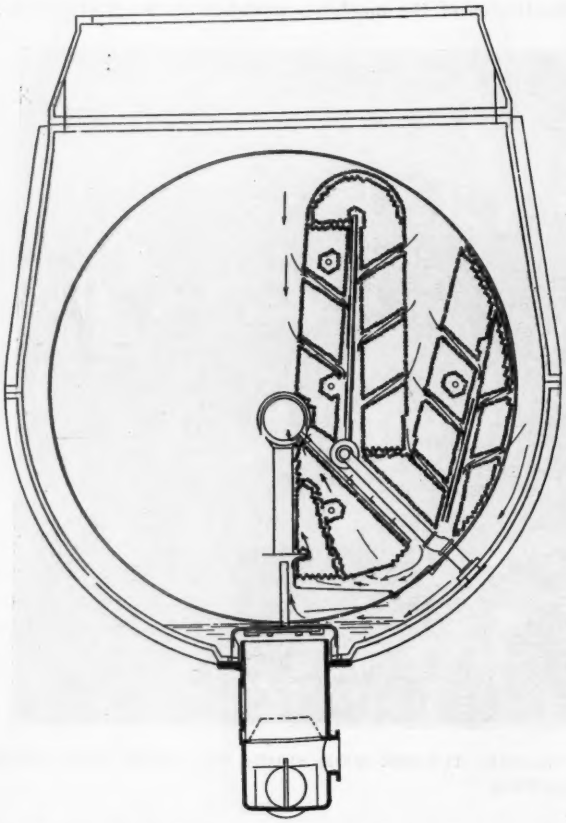


FIG. 2. ARRANGEMENT OF CONDENSER TUBES AND BAFFLES IN UNIT NO. 4

are interchangeable as a whole with those in the old units but the individual coils of the new type are not interchangeable with those of the old.

Stator coils for the last three units will be of the transposed type which consists of a number of asbestos insulated copper wires rectangular in section. These wires are so transposed that each wire occupies every position in the slot for the same linear distance as every other wire, the result being that voltage generated in any wire is the same as in any other wire in parallel with it. This effects the complete elimination of what is known as group eddy losses.

The capacity of the direct connected exciters has been increased to take care of the additional excitation current allowable due to the improved ventilation of the field. The exciter frame is consequently bigger than those on the first three machines and the overall length of the entire unit has been increased by just the amount that the exciter was lengthened. Several minor improvements have also been incorporated in the new generators to increase the ventilation of the stator coils.

Condenser Changes

For the last three turbines, the condensers have been redesigned and have been changed quite radically. A new layout of tubes and baffles has been made which has increased the amount of tube surface that comes in contact with the exhaust steam at the peripheral entrance of the tube bank and allows for a shorter and quicker path of the steam through the tubes. No tests have been run as yet on the new condensers to determine whether they are operating more efficiently than the earlier ones but observation during the regular operation of the No. 4 unit tends to show that the new machine carries about 0.1 in. better vacuum than the old.

Figure 2 shows the arrangement of tubes and baffles in the condenser. This shows the manner in which the tube clusters are symmetrically arranged about the center line. The lower quarter segment is separated from the rest of the condenser by baffles that run out radially at 45 deg. from the axis. The tubes in this bottom quarter work as an air cooler to reduce the volume of air that has to be handled by the dry vacuum pump. In summer some steam may sweep through to this air-cooling section before it is condensed, but in winter condensation is complete before the steam has reached the bottom of the condenser. A pipe runs along the axis of the condenser with holes along the bottom that open into the air-cooler section. The dry vacuum pump attached to the end of this pipe draws off all the air and gas that gathers in the condenser.

New Arrangement of Hotwell

The hotwell of the condenser has been redesigned and made an entirely separate tank. On each of the first three machines the hotwell was attached directly to the bottom of the condenser. On the new units the hotwell is a cylindrical tank set at one side and entirely separate from the condenser proper. This furnishes a larger storage capacity than the old arrangement and also allows greater accessibility. The condensate flows by gravity from a small collecting pot in the bottom of the condenser directly into the hotwell. A vent runs from the top of the hotwell back into the condenser so that any gas or air that may be carried over by the condensate is returned to the condenser where it is picked up by the dry vacuum pump and discharged to the atmosphere.

Water level in the hotwell is controlled automatically by means of floats. When the level of the tank gets down to a certain point, a float automatically manipulates valves which allow water from the feed water storage tank to flow back through the condenser and into the hotwell. When the level in the hotwell tank rises to a certain predetermined level, another float operates a bypass valve on the discharge side of the hotwell pump. This allows part of the condensate from the hotwell pump to be pumped back into the storage tanks. When the low water float in the hotwell operates, the water that is let into the condenser from the storage tanks undergoes a slight flashing effect. This liberates whatever air may have become entrained in

the water while it was standing in the open tanks. The operators have discovered that they can get a continuous deaeration of the condensate storage by holding down the low water float, thus allowing water from the storage tanks to pass into the condenser. This keeps an abnormally high level in the hotwell which automatically opens the high water float and discharges the condensate back into the storage tanks.

Combination Hotwell and Boiler Feed Pump

An interesting change has been made in the method of driving the hotwell pump. The first units are arranged with the hotwell and boiler feed pumps driven in tandem by the same motor or turbine, each condenser having both a turbine-driven and motor-driven set of pumps. The hotwell pumps are quite noisy in this combination. One reason for this is that the driving motor is designed to meet the requirements of the boiler feed pump because this pump is subjected to much heavier duty than that for the hotwell. The consequence is that the hotwell pump operates at a higher speed than is normally required of a pump designed for such service. This high speed causes cavitation and disturbed flow of the water through the hotwell pump.

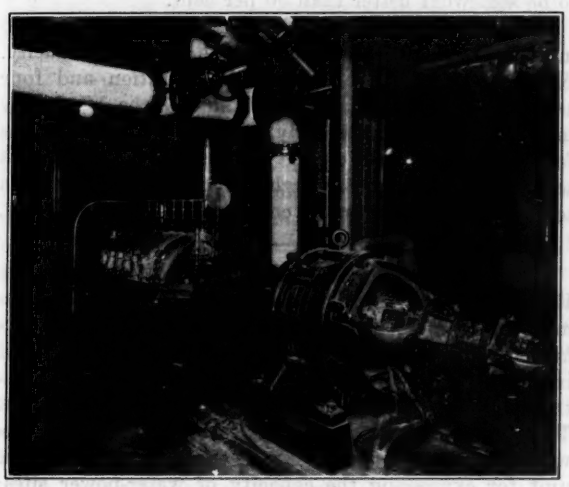


FIG. 3. ELECTRICALLY-DRIVEN BOILER FEED PUMP FOR UNIT NO. 4. CONSISTING OF MOTOR, PUMP, A.C. GENERATOR WITH EXCITER

In order to eliminate this trouble, some method of reducing the speed was sought. The first scheme hit upon was to reduce the speed of the hotwell pump by inserting reducing gears ahead of the pump on the common shaft. This idea was abandoned because the reducing gears would have crowded the available space too much for easy operation. It was finally decided to get the necessary speed reduction by means of an electrical coupling between the feed pump and the hotwell pump shafts. This has been done in the following manner:

A 700-hp. direct-current motor is connected directly to the boiler feed pump. This motor has a speed variation from 1000 to 1200 r.p.m. Coupled on the tail end of the pump shaft is a 125-kv.a. 60-cycle, 220-v. a.c. generator. This generator is connected to a 100-hp. squirrel cage induction motor with a synchronous speed of 900 r.p.m., which drives the hotwell pump.

Operation of this combination has worked out as planned. At full load the boiler feed pump motor operating at 1200 r.p.m. delivers power at 60 cycles through the shaft-end a.c. generator described above, to the terminals of the hotwell motor which runs at 870 r.p.m. As the demand for boiler feed water drops off, the driving motor is slowed down. In consequence, the frequency of the a.c. generator drops off and the hotwell pump slows down proportionately. At the lowest operating speed of the feed pump which is 1000 r.p.m., the a.c. generator is delivering its power at 50 cycles, thus driving the hotwell motor at (nominally) 720 r.p.m. This arrangement allows the hotwell pump to be placed nearer to the hotwell than with the old combination, reduces the length of the pipe from the hotwell to the pump and increases the suction head on the pump by the amount that was formerly lost due to friction in the pipe. The pump can also be placed in a much more convenient position for inspection and overhauling.

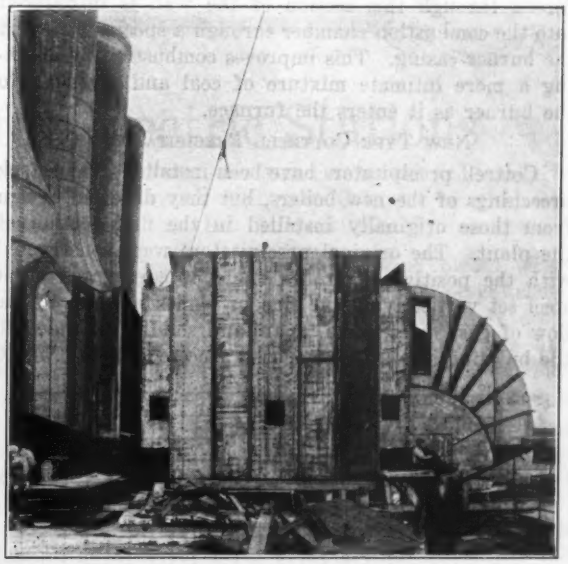


FIG. 4. COTTRELL PRECIPITATOR HOUSING DURING ERECTION

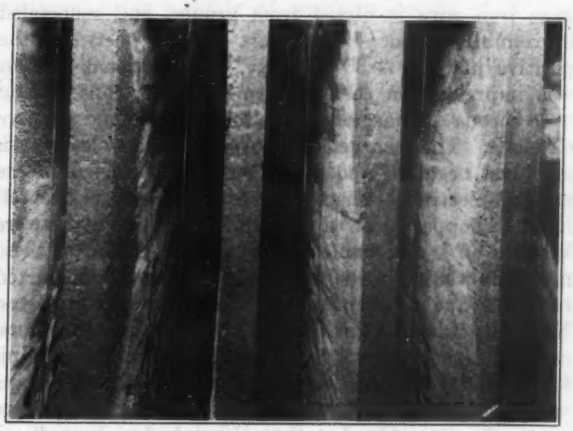


FIG. 5. SECTION OF PRECIPITATOR SHOWING ARRANGEMENT OF POSITIVE CONCRETE PLATES AND NEGATIVE WIRES

Boilers Are Practically Duplicates

The three boilers that have been installed to serve the new turbines have been only slightly modified from the eight boilers already in the plant. Part of the hollow side walls that were used for cooling the secondary air have been partitioned off and the air that is forced through this section of the wall is introduced into the combustion chamber through a special fitting in the burner casing. This improves combustion by effecting a more intimate mixture of coal and air close to the burner as it enters the furnace.

New Type Cottrell Precipitators

Cottrell precipitators have been installed in the stack breechings of the new boilers, but they differ in design from those originally installed in the first section of the plant. The original precipitators were constructed with the positive electrodes made of corrugated sheet steel set vertically in the flue in planes parallel to the flow of gas, spaced 4 in. apart and solidly grounded to the building steel. The negative electrodes were No. 10

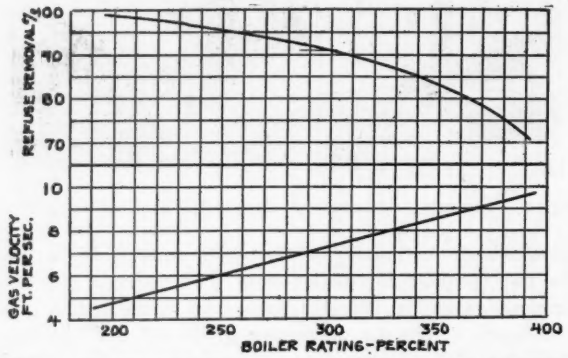


FIG. 6. REFUSE REMOVED FROM STACK GASES BY COTTRELL PRECIPITATOR

gage iron wire insulated from ground and suspended horizontally about 6 in. apart midway between the positive plates. A 35 to 50-kv. unidirectional current was impressed on the negative electrode, thus setting up a corona discharge between the negative and positive elements. This charged the suspended particles of ash and dust negatively so that they were attracted to the positive electrodes where they collected and either fell into the hopper below due to their own weight or were knocked off by mechanical rapping. Shortly after these machines went into operation, the negative wires started to break due to arcing from the wires to the plates. Naturally when a wire broke it fell across the others, causing a short circuit and shutting down the precipitator until the broken wire could be removed. Attempts were made to stop the arcing by reducing the voltage across the electrodes but the voltage had to be reduced so far that very little dust was precipitated from the gases. This type of precipitator was finally abandoned and a new type developed. An experimental unit of the new type has been in service in one of the breechings for about six months and has proved quite satisfactory in operation. The design of the new precipitator has been changed in the following manner:

Positive electrodes which were made of sheet iron have been replaced by reenforced concrete slabs. The ⅜-in. reenforcing rods in the concrete slabs act as the positive electrodes and are ground to the framework of the building. The slabs are 2 in. thick and the reenforcing rods are placed in the slabs vertically at 6-in. intervals. Two sets of slabs are used 18 ft. high, 6 ft. wide and spaced at 8-in. intervals with their sides parallel to the flow of gas.

Negative electrodes are made of No. 10 gage iron wire as before, but the wires are hung vertically instead of horizontally. A heavy weight is placed on the end, so that the wire is always taut. If one breaks due to corrosion or arcing, it merely drops clear of the other wires to the bottom of the precipitator housing.

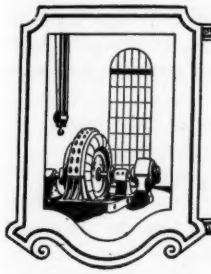
Results of tests run on the experimental precipitator show that the dust removal is very high. The curves in Fig. 6 show a dust removal of 91 at 300 per cent boiler rating and an even higher removal at lower ratings. The integrated removal at all ratings promises to be somewhat better than 90 per cent.

The coal preparation plant has been extended to meet the requirements of the additional boiler capacity. A second Bradford breaker is in operation and four additional 6-t. mills have been added to the 14 already installed. Work has already begun on the foundations for the last section of the preparation plant. This section will be large enough for ten mills, making a total of 28 mills to furnish coal for the completed plant.

According to an announcement by the American Engineering Standards Committee, a national agreement on the methods of rating the water power of rivers has been tentatively reached. As the question is one of international importance, the co-operation of other countries is being sought before any final decision is made. The committee has tentatively decided that the kilowatt should be used instead of the horsepower as the unit for expressing the capacity of water-power sites; that the capacity shown should express the theoretical potential power without deductions for the losses, which are sure to occur in water wheels, generators, transformers, etc.; and that the capacity should be stated for two rates of flow—one called the 90 per cent-of-time flow corresponding to a flow available 90 per cent of the time, and the other called the 50 per cent-of-time flow corresponding to the flow available one half of the time.

It is the desire of the committee to have these tentative rules discussed fully and frankly by everyone interested in hydraulic development in this country to the end that they may be so modified that as finally adopted they will represent the best American opinion. This problem is also being taken up internationally through the International Electrotechnical Commission with a view to the adoption of Standards, internationally, if possible.

Among the companies in Germany devoting attention to the production of high-speed steam turbines is the Waggon und Maschinenbau Gesellschaft of Gorlitz, which has recently completed a turbine to develop from 22,000 to 27,500 kw. when running at 3000 r.p.m. with a 96 per cent vacuum. A feature of the machine is the division of the low pressure portion into four separate compartments in a single casing. The same company is at present construction a high-speed turbine of the same type with a capacity of 33,000 kw.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Grounding Systems for Electric Stations

GROUNDING PROCEDURE IS USUALLY NOT GIVEN MUCH THOUGHT, YET THE CHARACTER OF A GROUND IS OF CONSIDERABLE IMPORTANCE. THIS ARTICLE DISCUSSES GROUNDING FROM BOTH A PRACTICAL AND THEORETICAL VIEWPOINT. BY C. M. RHOADES*

GROUNDING systems are provided to produce, as nearly as possible, a surface under and around a station which shall be at uniform potential and as nearly zero or absolute earth potential as possible. The purpose of this is to insure that in general all parts of apparatus, other than live parts, shall be at ground potential, as well as to insure that operators and attendants shall be at ground potential at all times. Also, by providing such a ground surface of uniform potential under and surrounding the station, there can exist no difference of potential in a short distance great enough to shock or injure an attendant when short circuits or other abnormal occurrences take place.

In order to accomplish this, a ground bus should surround the building or substation structure, which will act as a common ground bus for the station. Additional busses may be placed to suit the arrangement of equipment and attached to the common ground bus at both ends.

METHOD OF SECURING GROUND

The common ground bus should be connected by copper conductors to multiple driven pipes, immediately adjacent to the station, and also to all other available ground sources, such as water piping, wells, plates buried in river beds or swampy ground, etc. This assures a ground of low resistance—and if possible the resistance to ground should not exceed one ohm, and this may be measured by the point-to-point method between each ground plate or pipe and a group of pipes. The conductors from the bus to the ground sources should be taken off the bus at various places distributed throughout the bus.

If it is not possible, because of the nature of the soil, to drive pipes adjacent to the station, then copper cables may be buried under the surface of the ground and run in radial directions from the common ground bus to act in lieu of the multiple driven pipes.

ELECTRODES VS. PLATES

Driven pipes or rods possess many advantages over other forms of electrodes, such as buried plates, buried strips, coils of wire, etc. Chief among the advantages of the pipe or rod is the low cost and simplicity of driving, as compared to the task of excavating for and installing the buried form of electrode. Moreover the ground area required by a driven pipe or rod is small, which is a decided advantage in some places where excavation is out of the question because of restricted space or pavements. Another noteworthy advantage is that the connection between the ground wire and the driven pipe or rod can be made above the surface of the ground, which enables easier inspection and testing and eliminates the possibility of a defect being obscured, such as a broken ground wire below the ground surface caused by corrosion or mechanical thrusts and shifting caused by frost.

An analysis of the electrical resistance to earth formed by different types of electrodes shows that the driven pipes or rods compare very favorably with any of their competitors and have this outstanding advantage: that probably three or four may be driven and connected in parallel at a cost usually less than that of one of the buried electrodes, and thus it is possible to obtain a very much lower net ground resistance with driven pipes or rods for a given cost.

Where permanent moisture is at a considerable depth in soil, the driven pipes or rods have an obvious advantage, being capable of reaching depths of 20 feet or more where the soil is of friable texture. From the standpoint of maintenance and artificial treatment the driven pipes or rods hold a superior rating.

Galvanized pipe is not necessary, though of course it possesses obvious advantages in resisting corrosion and also simplifies the task of getting a good electrical connection to the electrode. From the standpoint of resistance no difference can be observed between black iron pipe and galvanized iron pipe of a given size, providing the former has a clean surface with no paint, grease or other insulating coatings. It would seem that, for stations and sub-stations, extra heavy and possibly in some cases double extra heavy pipe would be warranted, particularly where the soil conditions are such as to promote corrosion.

It may be concluded that a 1-inch pipe driven 10 ft. in the ground has about the same resistance as a plate 2 ft. square buried in the ground and that five to ten pipes may be installed at the same cost as one plate. For mechanical reasons a pipe too small in diameter should not be used. Where pipes cannot be used on account of rock or shallow soil, plates or radial cables buried in the ground parallel to the surface are recommended.

Copper-covered steel ground rods have in general

*Construction Engineering Department, General Electric Co.

the same characteristics as pipe, except that the copper-covered rod will probably resist corrosion over a somewhat longer period than pipe.

What to Ground

To the common ground bus should be connected, by individual copper conductors, the frames of all generators, synchronous condensers, converters, motors, etc., transformer tanks, oil circuit breaker tanks or frames, generator and transformer neutrals, secondaries and cases of current and potential transformers. Also to the common ground bus should be connected each steel column of the building or structure by a copper conductor.

Back of each switchboard should be a secondary ground bus for grounding panel mounted apparatus, this bus, in turn, to be connected to the common ground bus.

Lightning arresters should be connected to a local pipe ground, made by driving pipes into the ground directly under the arresters. The resistance between all the pipes connected in multiple should not exceed 5 ohms. This local pipe ground for the arresters should, in turn, be connected by copper cables to the common ground bus.

Overhead ground wires on transmission lines should be brought to the station and connected to the common ground bus by copper cables. This will assist in relaying and may also help in lowering the resistance of the ground bus.

If the substation should include separate structures for a number of different voltages, there should be a ground bus surrounding each structure and these busses should be connected together by low resistance conductors.

Grounding of Switchgear in Isolated Phase Stations

In the case of isolated phase stations, the ground protection may be carried further, so that a ground on any phase may be used to clear that section of the bus or station at fault. This can be done by providing a fault relay protective scheme, which would consist of having a fault ground bus for each section of the main bus. These sections of fault busses, in turn, should be connected to the common ground bus through a current transformer so that, in case of a fault, the current will flow to the common ground bus through the current transformer, which operates a suitable relay and causes the opening of all circuit breakers through which current can flow to the bus section in trouble.

When this scheme is used it is necessary that all of the stationary metallic parts of the switchgear which are not at bus potential; the bases of all insulators on the bus and bus connections, as far as the protective current transformer; the bases and mechanism of disconnecting switches; the tanks and mechanism of all circuit breakers, and the frames or cases of instruments and protective transformers be connected to the ground fault bus and not to the common ground bus.

How to Determine Size of Ground Bus

The size of ground bus should be determined by the amount of current and the time of flow, based on a maximum allowable temperature rise which, in the case of bolted joints, should be limited to 250 deg. C., and, for brazed joints, to 450 deg. C. The ground bus may be either bar or cable but, for general practice and ease of attachment, bar is preferable.

Ground busses may be treated under two classes:

1. Stations having neutral ground resistance.
2. Stations having no neutral ground resistance.

For stations having neutral resistance the current that will flow through the ground bus and the time that this current will flow should be based on the rating of the neutral resistance.

For stations having no neutral resistance the current that will flow through the ground bus has a definite relation to the station capacity and number of machines. The time that this ground current will flow depends on the cause and nature of the ground and the operation of the relays. It is fairly safe to assume, however, in case the relays fail to function, that a ground of any magnitude will develop within 30 seconds into a three-phase short circuit, and the current through the ground bus will then be comparatively small. An equation for determining the size of ground bus and connections has been derived as follows:*

$$t = (10^{33\,(I^2 \div A^2)\,S} - 1)\ (T + 234)$$

$$\text{or} \quad \frac{t}{T + 234} = (10^{33\,(I^2 \div A^2)\,S} - 1)$$

$$\text{or} \quad 33\,\frac{I^2}{A^2}\,S = \log\left(\frac{t}{T + 234} + 1\right)$$

in which t = temperature rise in deg. C.
I = amperes
A = cross sections in cir. mils.
S = time in seconds
T = initial temperature in deg. C.

Substituting proper values for bolted joints we have

$t = 250$ deg. C.
$T = 26$ deg. C.

$$33\left(\frac{I^2}{A^2}\right)S = \log\left(\frac{250}{260} + 1\right)$$

$$\left(\frac{I}{A}\right)^2 = \frac{.00904}{S}$$

$$A^2 = \frac{I^2\,S}{.00904}$$

$$A = I\sqrt{\frac{S}{.00904}} \text{ cir. mils.}$$

$$\text{or} \quad A = I\sqrt{\frac{S}{.095}}$$

$$\text{or} \quad A = 10.5\ I\sqrt{S}$$

Substituting the proper values for brazed joints, we have

$t = 450$ degrees C.
$T = 26$ degrees C.
$A = 8.7\ I\ S$

The cross-section of ground bus in circular mils can then be expressed as follows:

*This equation was drawn up by P. M. Currier of the Central Station Engineering Department and C. M. Rhoades of the Construction Engineering Department, both of the General Electric Company, and this equation is being used by the General Electric Company.

Cir. Mils = 10.5 $I\sqrt{S}$ for bolted joints (1)

Cir. Mils = 8.7 $I\sqrt{S}$ for brazed joints (2)

Where I = current flow to ground and S = time of current flow in seconds.

For example: Assume a station with neutral grounding resistor rated 2500 amp. for two minutes. Substituting in Formula (1) we have:

Cir. Mils = 10.5 × 2500 × 10.9 — 270,000 cir. mils or 1 in. by ¼-in. bar.

For stations without neutral resistance, the current flow is a function of the number of machines and their reactance. For distributed pole machines the sustained single-phase line-to-neutral short circuit current is 2.5 times the sustained three-phase short circuit current for one machine. If there are two or more machines with the neutral of only one grounded, then the ratio of single-phase to three-phase short circuit current is less than 2.5, and for 10 similar machines in multiple the ratio is about 1.9. For salient pole machines the ratio of single-phase sustained short circuit current to three-phase is two for one machine and about 1.1 for 10 machines in multiple, with the neutral of one grounded.

Assuming distributed pole machines with 100 per cent sustained reactance, and ratio of single-phase to three-phase sustained short circuits varying from 2.5 to 1.9, also assuming the time of short circuit to be 30 seconds, we can reduce formulas 1 and 2 to the form.

Cir. Mils = KI (3)

in which I is the normal current of the total number of machines in the station and K has the values shown in Table I.

TABLE I. FACTOR K FOR DISTRIBUTED POLE MACHINES

No. of Machines	Bolted Joints	Brazed Joints
1	144.0	119.0
2	139.0	114.5
3	134.0	111.0
4	129.5	107.0
5	125.5	103.6
6	121.5	100.2
7	118.0	97.5
8	114.2	94.5
9	111.0	92.0
10	108.2	89.5

Example: Take a station with four 25,000 kv.a., 13,200 v. machines. The normal station current equals 4360 amp. Then KI = 129.5 × 4360 = 565,000 cir. mils or approximately 2¼ by ¼-in. bar.

(To be continued)

EDITOR'S NOTE: In a subsequent issue Mr. Rhoades will take up in detail the grounding requirements for various pieces of apparatus, and methods for artificially treating the soil where the resistivity is high.

Electrical Features of Bayside Station*

NEW PLANT OF WISCONSIN PUBLIC SERVICE CO. AT GREEN BAY, WIS., CONTAINS ELECTRICAL EQUIPMENT LAID OUT FOR CONVENIENCE, ECONOMY AND RELIABILITY OF SERVICE AS AUXILIARY TO HYDRO PLANTS

AT THE NEW Bayside Station of the Wisconsin Public Service Co. at Green Bay, Wis., the mechanical equipment of which is described elsewhere in this issue, the electrical equipment is laid out so as to be convenient of access and operation and to provide the utmost reliability of performance and safety for operators. Electrical control of the station is centered in the control room shown in Fig. 1. All busses, switches, transformers and electrical accessories are concentrated in the electrical gallery, which is located at the west end of the station and separated from it only by the turbine room wall. A cross-section through this electrical gallery is shown in Fig. 5. There are four floors, as shown; the top one is the control room with a 4-ft. space just below it for running the conduits from the control boards. The third floor at present is vacant but is designed to take additional oil switches and bus structure as future requirements demand. On the second floor are located the 13,000-v. oil switches for the existing installation, while the lower floor contains busses, reactors and the like. Windows of the control room overlook the 66-kv. outdoor substation, Fig. 4, while the main 7500-kv.a., 66-kv. power transformers and 500-kv.a., 2300-v. station transformers are just outside the wall of the electrical gallery, between it and the substation. Lighting transformers and switching equipment for 2300-v. and 230/115-v. circuits are located in a substation on the second floor of the office section of the building, which is between the boiler room and the coal handling section.

As noted elsewhere, Bayside Station is designed to act as an auxiliary to the hydro plants of the Wisconsin Public Service Co. system. Its generating capacity at present is 20,000 kw. in two units, but this will be increased as the load demands. Power is generated at 13,200 v. This is stepped up to 66,000 v. for transmission over four circuits to connect with the system at a point about two miles west of the station. In addition to these lines, three 13,000-v. circuits now leave the station to supply power to the surrounding districts. One of these 13,000-v. lines will consist of an underground cable under the Fox River to supply power to a large paper mill. Load dispatching for the system is done at the substation of the Wisconsin Public Service Co. in Green Bay.

Transmission line towers to carry the 66-kv. lines are of galvanized structural steel and of the double circuit type. They are set on concrete foundations designed to develop the full strength of the towers.

Two generators operate at 1800 r.p.m., 13,200 v., 3 phase, 60 cycle, and are rated at 10,000 kw., 12,500 kv.a. These machines do not have direct shaft-driven exciters, but take their excitation from two separate exciters installed on the turbine room floor. One exciter is a 100-kw., 250-v. motor-generator set driven by a 2300-v. motor; the other is a 100-kw., 250-v. dual drive set, the generator shaft being connected on one end to a 2300-v. motor and on the other to a single stage non-condensing

*Mechanical equipment of Bayside Station is described elsewhere in this issue.

FIG. 1. MAIN CONTROL ROOM, SHOWING BENCH BOARD FOR GENERATOR AND SUBSTATION CONTROL, AUXILIARY FEEDER PANELS AT LEFT AND STORAGE BATTERY NEAR WALL

steam turbine. The latter unit is arranged so that it will be driven normally by the motor but if the speed of this drops too much, due to electrical disturbances, the turbine will automatically pick up the load. It will be possible also to have the turbine carry all of this load or part of it in conjunction with the motor in case this is necessary to control the heat balance.

Each exciter supplies its own exciter bus and each is designed to supply sufficient power to excite both main generators, if necessary. Under normal condi-

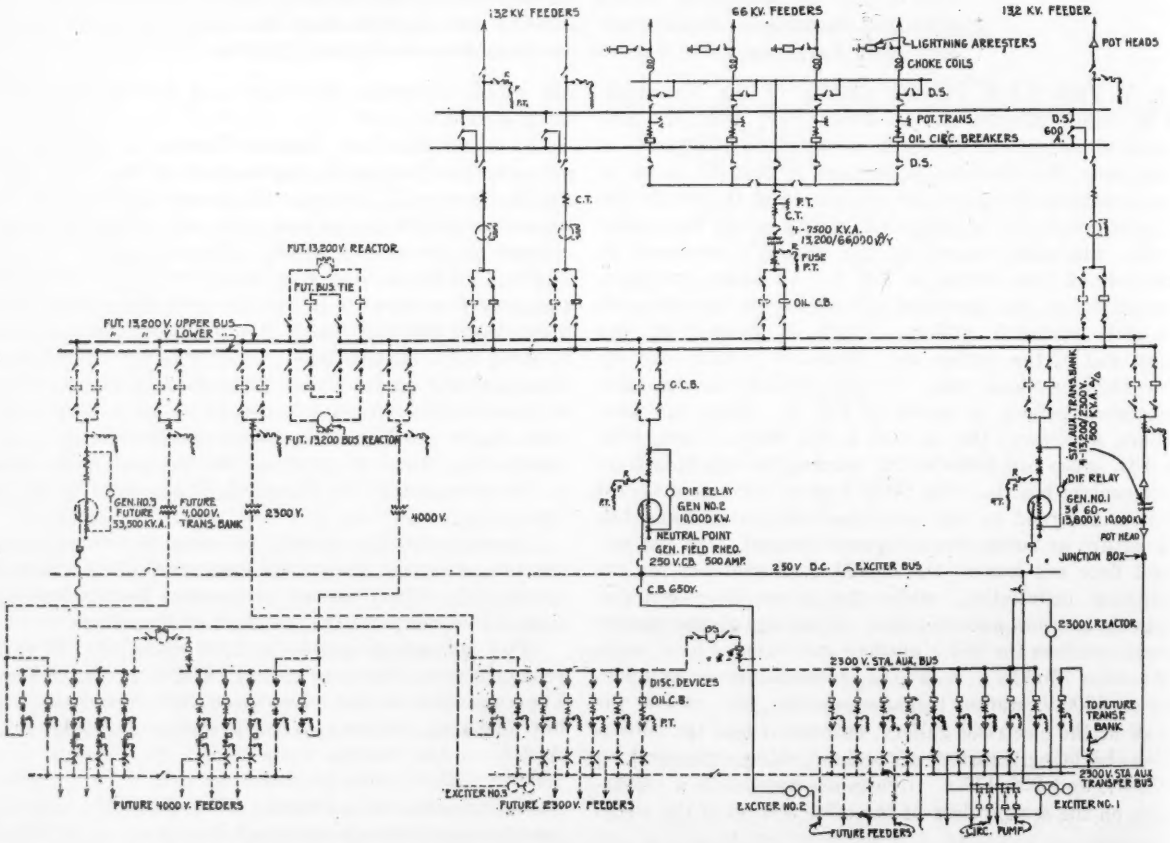


FIG. 2. SINGLE LINE DIAGRAM OF ELECTRICAL CONNECTIONS OF BAYSIDE STATION

tions, it is expected that the dual drive unit will be used to furnish the excitation. The two exciter busses can be tied together through a circuit breaker, so that either exciter can supply either main unit or both.

Complete control of the exciters and of the condenser circulating pumps of each unit is centered on control boards located beside each exciter and operated by the pump operator. These boards carry the oil switches, meters, relays and interlock controls and a signal system is provided to connect with the turbine operating platform and the electrical control room. No excitation circuits are handled in the control room. The above circuits are shown on the single line diagram, Fig. 2.

Essential auxiliaries, such as boiler feed pumps, one exciter, hotwell pumps and one service pump are driven by steam turbines, so that they will not be affected by electrical disturbances and will also provide exhaust steam for feed water heating. The circulating pump motors, exciter motors, pulverizing mill motors and air preheater motors are all 2300-v. motors and the remaining auxiliary motors are 220 v.

For supplying the 2300-v. motor circuits, a bank of 13,200/2300-v. outdoor O. I. S. C. transformers is installed. To insure continuous service on the 2300-v. bus, the auxiliary transformer bank feeding it is connected so that it receives power either from the station main generators or from the high-tension substation.

Pulverizer driving motors and air preheater motors are connected to this 2300-v. bus through suitable switches and protective devices and the controls for these motors are all grouped on the boiler control panel on the boiler operating floor. Since exciter and circulating pump motors are also controlled right at the units, it can be seen that none of the 2300-v. auxiliaries are handled in the control room but only the circuits of the 2300-v. transformers.

Each motor is supplied by two separate circuits to either of which the motors can be thrown by double-throw switches located on their several control boards.

Direct current for the magnetic separator and for the feeder motors on the No. 1 pulverizer mills is supplied by a 5.75-kw. motor-generator set. The feeder circuits of these units are handled from a direct current panel in the boiler room substation with suitable switches on the boiler control board.

From the 2300-v. bus, as shown on Fig. 2, connections are made to two 300-kv.a. banks of 2300/230-115-v. transformers for the lighting circuits. One of these banks supplies the lighting circuits of the boiler room, office and machine shop, and through an entirely separate circuit, the turbine room and the electrical gallery lighting circuits. An emergency bank of these transformers is installed, with suitable emergency bus and throw-over arrangements. Each of these separate lighting circuits is equipped with a voltage regulator, so that in case it should be necessary to raise the generated voltage temporarily, due to system disturbances, the lighting voltage will remain constant. In case of low voltage or failure of the lighting supply for any reason, the 60-cell storage battery is automatically cut in to supply lighting. Water screen motor and battery charger are supplied through a 2300/220-v. transformer bank connected directly to the main 2300-v. bus. From the first or normal bank of 2300/220-v. station auxiliary transformers power is taken by the main 220-v. bus to supply the 220-v. motors driving service pumps, conveyors, machine shop equipment, and the like.

FIG. 3. 13-KV. OIL SWITCHES IN ELECTRICAL GALLERY. DISCONNECTS ARE GANG OPERATED FROM HANDLES SHOWN WITH MECHANICAL INTERLOCKS

As noted above, main 13,000-v. oil switches and 2300-v. oil switches are located on the second floor of the electrical gallery, together with the gang operated disconnects. Figure 3 is a view along this floor showing the switch compartments at the right and the handles

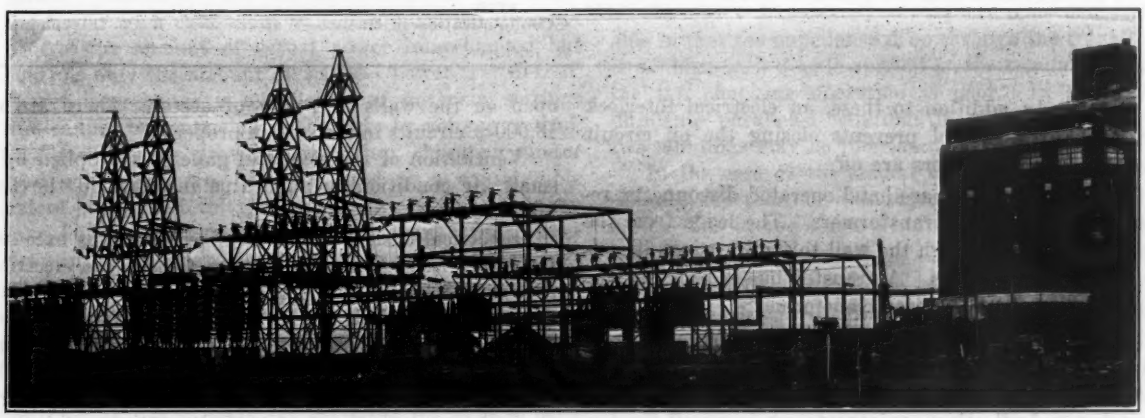


FIG. 4. GENERAL VIEW OF OUTDOOR SUBSTATION, WITH ELECTRICAL GALLERY AT RIGHT AND POWER TRANSFORMERS NEAR THE GALLERY WALL

by which the disconnects are operated from this floor. Switches are of the truck type and are thus made convenient and safe. The view also shows the mechanical interlocks which make it impossible to open the disconnects while the circuit breaker is closed. This mechanical interlock also prevents closing the disconnects if the oil circuit breaker has been left in the closed position after an inspection or after maintenance work. Another interlock prevents removal of cell doors if the breaker is closed. In addition to these, an electrical interlock on the switch control prevents closing the oil circuit breaker if the cell doors are off.

On the floor below are hand operated disconnects, reactors and potential transformers. The leads from the busses pass out through the wall through casings directly to the transformers. A transfer bus is provided for cutting in the spare power transformer.

At present a single 13,200-v. bus system is used but provision has been made for a double bus system when the capacity of the station increases. Busses, oil switches and all other equipment are separated by vertical barriers but the vertical isolated phase system is not used in this case.

In the main control room, Fig. 1, the bench board carries controls for the main generators and the outgoing feeders. Behind this is a panel carrying the station watt-hour meters, and behind this, near the wall, is the storage battery with its charging set. Facing the bench board is the direct current-panel. At the left of the picture is shown the feeder control board for the 2300-v. transformers and feeders. Circuits are run from the various control boards in conduit, which is all open on the walls and easy of access. There are no 13,000-v. circuits in the station proper.

Ventilation of the electrical gallery is supplied by a small air conditioning apparatus installed in the turbine room.

Electrical design of the Bayside plant was executed for the Wisconsin Public Service Co. by the electrical engineering department of Byllesby Engrg. & Man. Corp., supervised by R. M. Stanley, electrical engineer for the latter. Electrical construction work, including the erection of transmission line, was supervised by H. H. Fisher of the Byllesby Engrg. & Man. Corp. O. J. Peters is chief operator of the station under J. L. Hartney, chief engineer. We are indebted to these men for data, illustrations and the most cordial co-operation.

Principal Electrical Equipment at Bayside Station

Generators and Auxiliaries

2 Allis-Chalmers Mfg. Co. main generators, 10,000 kw., 12,500 kv.a., type AT-4-42-69½, 3 phase, 60 cycle, 14,000 v., 516 amp., maximum excitation, 173 amp. at 250 v., 1800 r.p.m. Turbines listed with mechanical equipment.

1 General Electric Co. motor-generator exciter set, generator 100 kw., Type CD, 275/275 v., d.c., 364 amp., driven at 1160 r.p.m. by 150 hp., Type K.T.P. 3-phase, 60-cycle, 2300-v., full voltage starting motor.

1 General Electric Co. duplex drive exciter set. Generator, 100 kw., 275/275 v., d.c., 364 amp., 1200 r.p.m. Drive by turbine and motor as per list of mechanical equipment.

1 Electric Storage Battery Co., 60-cell chloride accumulator. Capacity 152 amp. for 1, in. at 1.75 v. per cell.

1 General Electric Co. battery charger; generator 10 kw., 170 v., 1800 r.p.m., shunt wound; driven by 15 hp., Type KT-954, 3-phase, 60 cycle, 1800 r.p.m. motor.

1 General Electric Co., motor-generator set for charging magnetic pulley and supplying d.c. for feeders of No. 1 pulverizer mills. Generator 5.75 kw., 250/250 v., d.c.; driven at 1800 r.p.m. by 7.5 hp., 3-phase, 60-cycle, 220-v. motor.

Substation and Transmission Line Equipment

9 General Electric Co. 73,000-v. oil circuit breakers, FHK 0136 outdoor type with MK 4 motor mechanism.

4 Sets—General Electric Co. Oxide Film Lightning arresters, 73 kv. with 4 Delta-Star Electric Co. disconnecting switches.

996 Sets—Lapp Insulator Co. suspension insulators for outdoor substation.

19 Delta-Star Electric Co., 3-pole, 73-kv., 600-amp., type P.M. disconnecting switches, remote controlled, gang operated.

12 Delta-Star Electric Co., 73-kv., 300 amp. choke coils.

4 General Electric current transformers 600/5 amp. for indicating instruments.

4 General Electric Co. 66,000/110-v. potential transformers.

Structural steel for outdoor substation—Industrial Eng. & Sales Service.

Galvanized steel high tension transmission towers—Aermotor Co.

3770 Ohio Brass Co. ball and socket type suspension insulators for transmission line.

Copper cable, 7 strand, 00, hard drawn copper—Anaconda Copper Co.

Galvanized steel wire, ⅜ in., 7 strand—Roebling & Sons.

Transformers

4 Allis-Chalmers Mfg. Co., 7500-kv.a. power transformers, outdoor type, O.I.S.C. single phase, 60 cycle, 69,300/13,800 v.

4 Westinghouse Electric & Mfg. Co. 500 kv.a. transformers, outdoor type, O.I.S.C. single phase, 60 cycle, 13,800/2300 v.

12 Westinghouse Electric & Mfg. Co. distribution transformers, O.I.S.C., single phase, 60 cycle, 2300/230-115 v.; 6 units, 100 kv.a.; 1 unit, 25 kv.a.; 2 units, 15 kv.a.; 3 units, 10 kv.a.

2 Westinghouse Electric & Mfg. Co. indoor induction feeder regulators, each 11.5 kv.a., single phase, 60 cycle, with motors, relays, controls, etc., for station lighting service.

Station Switches and Accessories

12 General Electric Co. oil circuit breakers, FH 203, truck type, six 13,000-v. and six 2300-v.

12 Delta-Star Electric Co. gang operated disconnecting switches, 13 kv.

3200 ft.—Baltimore Tube Co. copper bus bar 4 in. by ¼ in.

800 ft.—Rome Brass & Copper Co. copper bus bar, 2½ in. by ¼ in.

Bus Insulators—Delta-Star Electric Co.

Bus Reactors—General Electric Co.

4 General Electric Co., 230-v., double pole, d.c. magnetic switches for pulverizer feeder motors.

Miscellaneous Main Station Equipment

Meters and Instruments—General Electric Co.

Generator temperature recorders—Leeds & Northrup.

Frequency indicators—James G. Biddle.

Conduits and fittings—Graybar Electric Co. and Crouse-Hinds Co.

Multiple Conductor control cable—Safety Cable Co., General Electric Co.

Miscellaneous switchboard fittings—Delta-Star Electric Co.

Single conductor copper cable, 5000-v. and 1700-v., varn. camb. ins.; 600-v., reg. ins.—M. B. Austin Co.

Potheads—G. & W. Electrical Specialty Co.

Over current relays—Westinghouse Electric & Mfg. Co.

Solid copper wire for station lighting circuits, 600-v., rubber ins.—American Steel & Wire Co.

Direct current relays—General Electric Co.

Lighting circuit panels and cabinets—Westinghouse Electric & Mfg. Co.

Lighting fixtures—I. P. Frink; Russell Stahl.

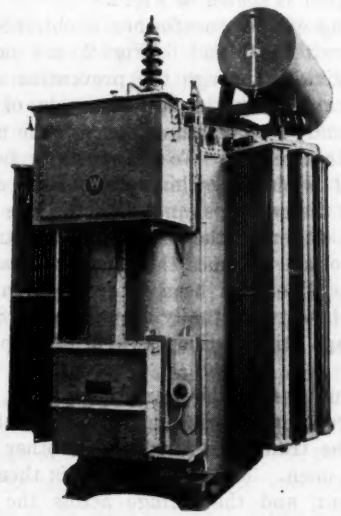
1 Buffalo Forge Co. 900 c.f.m. conoidal fan with 2 units of Aerofin tubes for ventilation of electrical gallery.

Fan driven by G.E., 3-hp., 220-v., 60-cycle, 600 r.p.m. motor.

1 Reed Air Filter Co. Type K.B.R.M., 20 by 20 by 4 in., air filter with washing and charging tanks. Electrical gallery ventilation system.

1 General Electric Co. oil filter press Type FP-10; 7-m. oil dryer and filter press, 10 g.p.m., 115/230-v. drying oven.

Communication in station—Western Electric Co. interphone.



Voltage Ratio Control by Tap Changing

THE DEVELOPMENT OF EQUIPMENT FOR TAP CHANGING UNDER LOAD HAS GIVEN ELECTRICAL ENGINEERS AN EXCELLENT MEANS OF CONTROLLING THE AMOUNT OF WATTLESS POWER INTERCHANGE BETWEEN TRANSMISSION SYSTEMS. THIS ARTICLE DISCUSSES NOT ONLY THE APPLICATION OF THIS EQUIPMENT BUT ALSO DETAILS OF CONSTRUCTION AND METHOD OF OPERATION. BY L. H. HILL*

DURING THE PAST few years there has been a growing demand for equipment suitable for changing the voltage ratio of transformers under load. Sufficient equipment has been built to demonstrate that apparatus of this sort has advantages which firmly establish it in the list of equipment available for bulk voltage regulation.

One of the most important applications for tap changing under load equipment is for use with transformers used to form an interconnection between two large systems or parts of systems. The function in this case is to control the transfer of wattless power between the two parts. If the voltages of two systems to be tied together at one point tend to vary with respect to each other, the wattless transfer would vary in proportion and in many cases would be excessive unless provisions were made to form a "flexible" tie—one whereby the voltage ratio might be varied to compensate for the difference in voltage between systems. Conversely, if the two system voltages were to remain constant, changing the voltage ratio of the interconnecting transformers would permit power factor control of the load transferred. Contrary to the popular conception, tap changing under load equipment in this application does not control the amount of actual power interchanged but controls only the amount of wattless power transferred. Power interchange is a function of governor settings and cannot be controlled in this case by voltage control.

Transformers provided with tap changing under load equipment are, however, used to a considerable extent as straight voltage regulators. In this case they may be used to compensate for line and transformer drop in transmission circuits or to maintain the voltage at secondary distribution busses between predetermined limits. There are also certain industrial applications where tap changing under load equipment has been used.

Equipments for changing taps under load have been built which are suitable for changing the voltage ratio of the transformer either in steps or along a smooth curve. The range to be covered by tap changing under load equipment generally varies from 10 to 20 per cent and in the case of the step-type equipment, the transitions are of the order of 2 to 4 per cent, generally about 2½ per cent.

Equipment for obtaining voltage control along a smooth curve finds its best field of application on the smaller units—where a large range is to be covered in small steps—such as 5000 kv.a. single phase or 15,000 kv.a. three phase or below, used for bus regulation, furnace control, or synchronous converter control. With the larger units, experience has shown that changing the voltage ratio in steps is entirely satisfactory.

Changing Voltage Ratio in Steps

There have been two general methods employed for changing the voltage ratio in steps: (1) those using duplicate paralleled windings in the transformer and (2) those using a single winding in the transformer.

The first case is a logical development from the use of two identical banks of transformers, one of which would carry double load, while the taps were changed on the other. The use of two transformers is objectionable in that the impedance drop through the transformer is doubled with double current so the regulation during the tap changing operation is poor. In the case of duplicate paralleled windings in the transformer, the two windings may be interlaced to minimize this effect.

In the case of the second method, a preventive resistance, reactance or auto-transformer is used to bridge across taps of the single winding during the transition period.

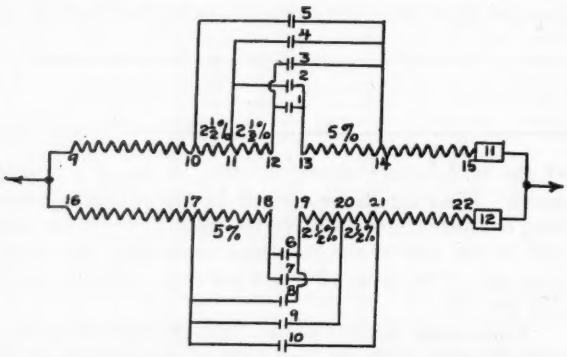
The Parallel Winding Method

The schematic diagram of a winding arranged to change taps by the parallel winding method is illustrated in Fig. 1. Each of the parallel windings is provided with taps and a suitable tap changer inside the tank designed to operate with the load disconnected. Each of the paralleled windings contains a circuit breaker which is mounted outside the case.

*Transformer Engineer, Westinghouse Electric and Mfg. Co.

When taps are changed, one of the paralleled circuits is opened by means of the circuit breaker in its respective section and the taps are changed while the winding carries no load. During this period the entire load is carried by the other winding. When the first circuit breaker closes, the two sections of the windings are paralleled with unequal taps and a circulating current exists. This is for a short time only, as the second breaker opens immediately, permitting the taps to be changed at no load on the second winding, while the first carries the total load. After this, the tap changing operation is completed by closing the breaker on the second winding with the result that the two paralleled sections operate on equal taps.

During the interval of tap changing, one of the paralleled windings carries double normal current. The



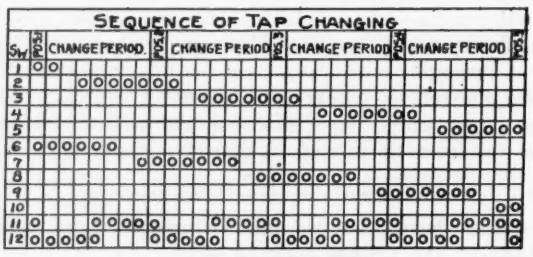


FIG. 1. SCHEMATIC DIAGRAM OF PARALLEL WINDING METHOD AND SEQUENCE CHART

windings have sufficient capacity to carry this abnormal current for a reasonable time, but obviously cannot carry it indefinitely. For this reason, current transformers are provided in each of the paralleled windings and are connected differentially to operate an alarm relay in case of an unbalance. A time delay relay in the circuit prevents operation due to the unbalance created during the normal tap changing operation.

Single Winding Method

The other methods used in addition to the parallel winding method fall into the class which uses a single winding in the transformer and a preventive coil of some type during the transition period from one tap to the next.

Probably the oldest form of tap changing under load equipment employed the Stillwell regulator principle, which uses a preventive resistance temporarily bridged across taps to limit the current during the transition period. A development from these was the use of a preventive auto-transformer with a mid-point tap and short-circuiting switch as shown in Fig. 2.

The full winding of the transformer is obtained in the circuit when switches 1 and 6, Fig. 2, are closed. The circuit then divides through the preventive auto-transformer, one-half being through one side of the auto-transformer, and one-half being through the other half in the opposite direction. To change taps, switch 6 is opened and 2 is closed. This connects the auto-transformer across the two taps, and since the line lead is attached to the center of the preventive auto-transformer, the line voltage becomes the same as it would have been had the line lead been attached to a tap mid-way between those two actually brought out. Similarly to change taps still further, switch 1 is opened and 6 closed.

For a short time during the transition period, one-half of the auto-transformer winding carries all of the load current of the transformer, while the other half of the winding is open. The load current is then the magnetizing current, and the voltage across the preventive auto-transformer tends to rise somewhat above normal. To limit this voltage to a low value, the design of the auto-transformer is such that the core becomes saturated when the voltage reaches a value slightly above normal.

Single Winding Method—with Self-Protecting Auto-Transformer

The preventive auto-transformer method using a short circuiting switch across the auto-transformer has recently been simplified by the elimination of a short-circuiting switch and the use of an auto-transformer designed to carry the transformer full load current in either half with the other half carrying no load.

Figure 3 illustrates schematically the winding arrangement when this method is used. To obtain the entire transformer winding in the circuit, switch 1 is closed and the current passes through the transformer winding and the one-half of the preventive auto-transformer. This gives a small impedance drop through the auto-transformer, which is in series with the transformer. Since the drop is almost entirely reactive, the effect on regulation is practically negligible at power factors above 65 per cent.

To change taps one step, switch 2 is closed, which places the auto-transformer across the two taps, giving a voltage on the mid-tap of the auto-transformer midway between the two actual tap voltages. To change taps another step, switch 1 is opened and the conditions become as before, with the other half of the auto-transformer carrying the full current of the transformer. It may be seen that by this development the process of tap changing has apparently reached its utmost simplicity for step-type tap changers—one switch operation to change taps, and in every other tap change the switch closes instead of opens.

Few switch operations and few circuit operations per tap change indicate long life with little maintenance. The actual number of switches and taps in the transformer, required for this method, is a minimum—approximately one-half as many as the number of operating voltages. Another important advantage is that since the auto-transformer is designed to carry full-load on either half of its winding, it is not overloaded during

the tap changing operation. With this method, there is, therefore, no winding which carries more than normal load during a tap change.

When full load current is passed through one-half of the auto-transformer with the other half open, the full load current of the main transformer becomes the exciting current of the auto-transformer. There are no neutralizing ampere turns from the other half so the transformer becomes a reactor. Air gaps are provided in the core to give low impedance when operating under this condition, which, of course, makes the exciting current when operating as an auto-transformer across taps, higher than it would be otherwise.

Figure 4 illustrates a 20,000-kv.a. unit designed for use in a three-phase bank to transform from 132,000 v. star to 12,000 v. delta using the simplified preventive auto method. These units are used for interconnecting parts of a large system. The tap changer is placed in the grounded end of the 132-kv. winding and covers a range of 20 per cent in eight 2½ per cent steps.

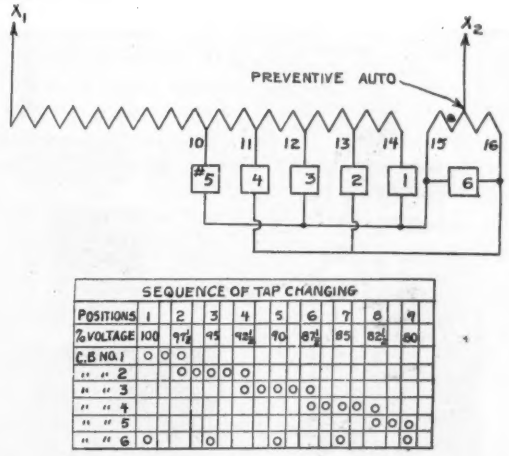
The tap leads are brought through the tank wall by means of suitable bushings which are connected to the circuit breakers contained in the steel house below. The leads between bushings and breakers are entirely enclosed, but the connections are made accessible by means of a removable plate on the front of the housing. Figure 5 shows the complete unit with this plate removed. Five breakers were used in this case to obtain the eight 2½ per cent steps as indicated by the schematic and sequence diagrams of Fig. 3.

The circuit breakers are operated entirely mechanically by means of the main drive shaft running through the center. Figure 6 shows a plan view of the tap changing equipment with three breakers removed to show the driving mechanism. The circuit breakers are closed mechanically by the cams on the drive shaft operating through simple linkages. The breakers are normally opened by the cam pushing the breaker over toggle but the action is such that the breakers are forced open if necessary, before the completion of the tap changing operation.

Figure 7 shows the general arrangement of the equipment. The hand-wheel normally revolves with the motor and is guarded by means of a hinged cover. In case it is desired to operate the equipment by hand, the cover is unlocked and is dropped down out of the way. The operation of opening the cover operates two switches; one disconnects the control circuits and the other lights a lamp on the switchboard indicating to the operator that he no longer has control of the bank. The operation of opening the cover also releases the motor brake to permit easy turning during hand operation. The hand-wheel is revolved until the desired position number is reached as indicated on the mechanical position indicator.

Remote control of this equipment is very simple. The apparatus on the switchboard consists of a position indicator for each unit, a control switch for each bank, and a test link for each unit to permit individual operation of any unit if desired. The operation of the control switch, either to raise or to lower the voltage, operates simultaneously the respective raise or lower three-pole contactor switches on each of the three tap changing mechanisms in a bank. As soon as the tap changing equipment starts to move, mechanically operated control switches on the mechanism, Fig. 8, close and complete the circuit until a tap changing operation has been completed, irrespective of the action of the operator.

Circuit breaking devices for tap changing service have entirely different conditions to meet than the ordinary circuit breaker. The ordinary breaker is designed for relatively infrequent operations with a few operations interrupting many times normal current at line voltage.

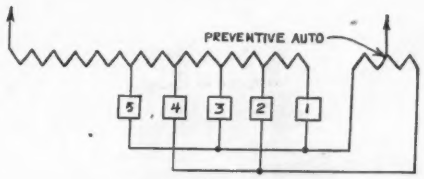


SEQUENCE OF TAP CHANGING

POSITIONS	1	2	3	4	5	6	7	8	9
% VOLTAGE	100	97½	95	92½	90	87½	85	82½	80
C.B NO. 1	o	o	o						
" " 2		o	o	o	o	o			
" " 3					o	o	o	o	o
" " 4							o	o	o
" " 5								o	o
" " 6	o			o			o		o

o = SWITCH CLOSED

FIG. 2. ARRANGEMENT USING SINGLE WINDING WITH PREVENTIVE AUTO-TRANSFORMER AND SHORT CIRCUITING SWITCH



	SEQUENCE OF TAP CHANGING								
POSITIONS	1	2	3	4	5	6	7	8	9
SW.-1	o	o							
2		o	o	o					
3				o	o	o			
4						o	o	o	
5								o	o

o = SWITCH CLOSED

FIG. 3. SINGLE WINDING METHOD USING SELF-PROTECTING PREVENTIVE AUTO-TRANSFORMER

On the other hand, the switch for tap changing duty is called upon merely to transfer current from one circuit to another and while it must be insulated for the service voltage, it opens but a small fraction of line voltage and usually not more than normal line current. Instead of being designed for a few operations with high interrupting capacity, it is designed to stand a great number of operations without losing its adjustment with very low interrupting capacity required.

Advantage of these requirements has been taken in the case of the transformer shown in the illustration at the head of this article. The result is a simple, compact and rugged mechanism with all operating parts outside of the main tank. The same simplified preventive-auto method of Fig. 3 is used. In principle the equipment is

the same as that illustrated in Fig. 6 except that the circuit-interrupting devices are different.

The transformer in this case is rated at 12,000 kv.a., and is designed for use in a three-phase bank to transform from 132,000 v. star to 11,500 v. delta. The tap changer is in the grounded end of the 132,000-v. winding and covers a range of 20 per cent in ten 2 per cent steps.

The tap-changing switches are contained in a separate oil-filled compartment on the side of and near the top of the transformer case. The operating mechanism is contained in the housing below, and the connecting tube encloses the drive shaft which enters the upper compartment through an oil tight stuffing box in the bottom.

The operating mechanism, Fig. 9, is similar to that used with the circuit breaker equipment except somewhat lighter and arranged for mounting directly on the tank wall.

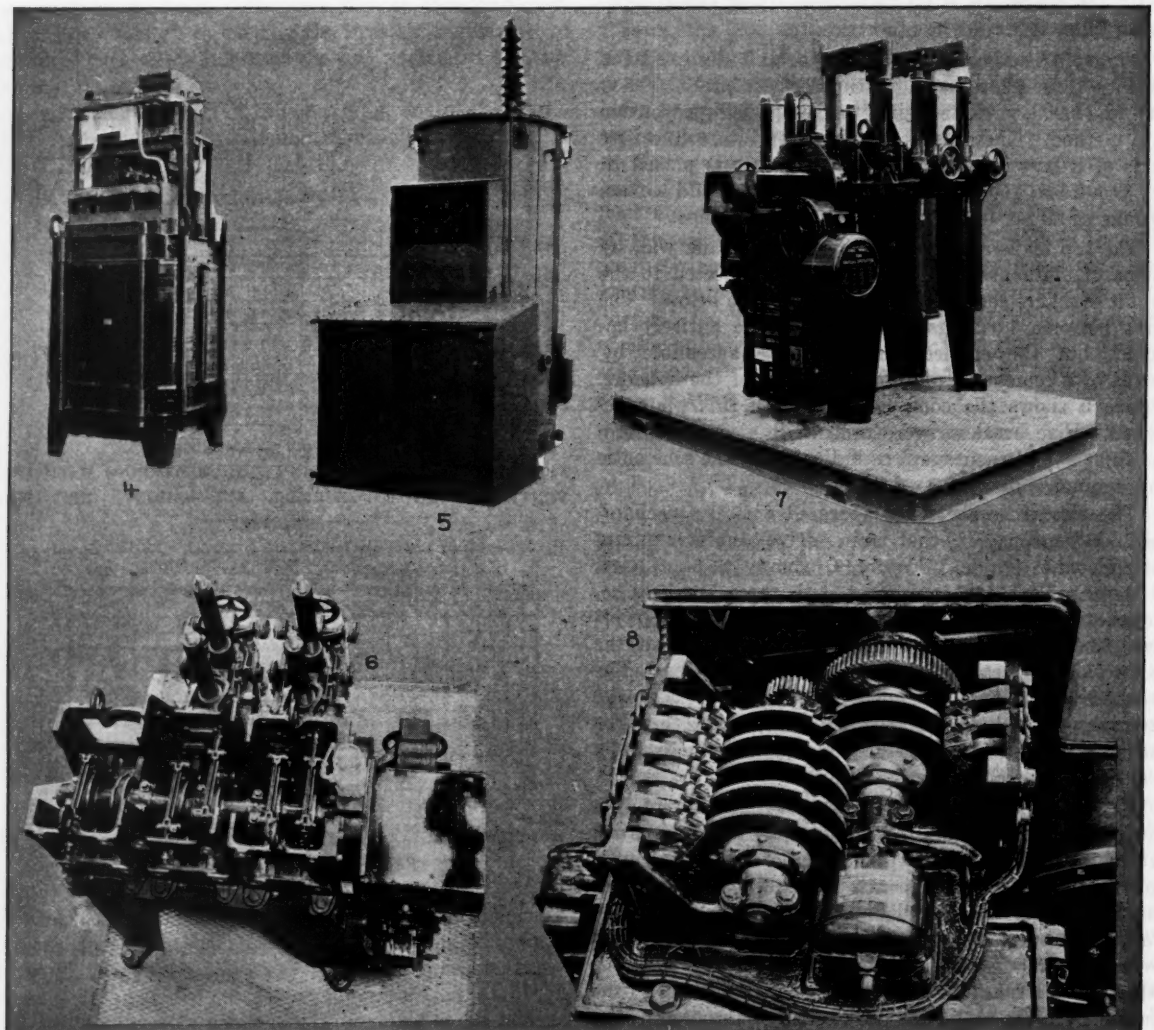
This particular equipment is used for bus voltage regulation, and the installation was the first built for automatic control of step-type units.

The mechanism is normally automatically motor operated, but is arranged for non-automatic or motor control by the operator as well as for hand operation. In the latter case, access to the mechanism can be secured by opening the door to the front of the mechanism which automatically disconnects the control circuit.

With automatic motor operation, remote control is initiated by a rise or fall in the low voltage potential acting through a long time relay. With motor operation controlled by the operator, remote control is started by a control switch at the switchboard. The control equipment when started, will automatically complete a change of taps regardless of further action on the part of the operator.

An interesting modification of the single winding method of tap changing is obtained if the two halves of the preventive auto-transformer are replaced by the two oppositely wound sections of a series transformer in combination with a small induction regulator.

This combination is called a step induction regulator and has been used principally for bus regulation and to



FIGS. 4—8. PHOTOGRAPHS OF TAP CHANGING EQUIPMENT

apply variable voltage in a smooth curve to furnace transformers, testing transformer, and rotary converters. It has also been applied to transformers used for interconnecting two systems.

Referring to Fig. 10, the switches 1, 2, 3, 4 and 5 are called selector switches, while A and B are called transfer switches. The induction regulator may be a standard feeder regulator with the addition of slip rings to make the rotor suitable for continuous rotation.

Rotation of the induction regulator rotor through 180 deg. changes the voltage in the stator winding from a maximum in one direction to a maximum in the other direction. In the application to step induction regulator equipment, the voltage of the regulator is added to or subtracted from a transformer tap to provide means for transferring from one tap position to the next and

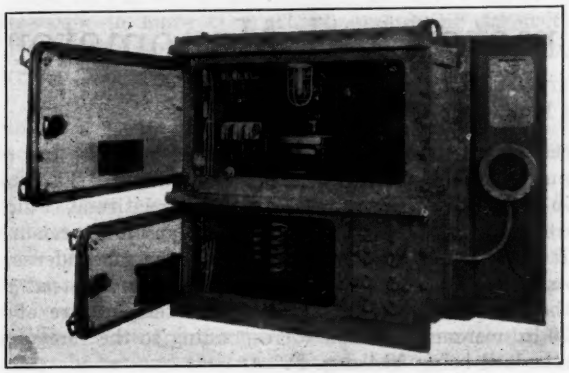


FIG. 9. TAP CHANGER OPERATING MECHANISM FOR 12,000-KV.A. TRANSFORMER

incidentally obtaining an infinite number of operating positions within the range of the equipment.

Referring to Fig. 10, if the entire voltage of the transformer winding is to be obtained, selector switch 1 and transfer switch A would be closed with the regulator rotor in the position of zero buck and boost. To reduce the effective transformer coil voltage, the regulator is rotated to increase the voltage. At the position of maximum regulator voltage, the series transformer is designed so that the voltage of each half of the series winding is exactly the same as one-half the tap voltage.

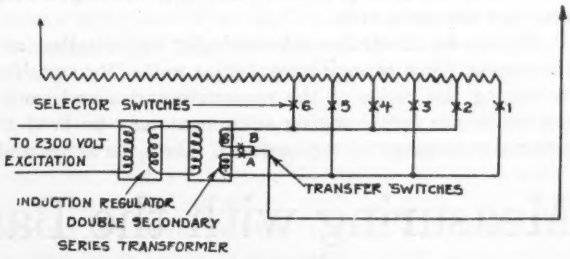
At this point switches 2 and B may be closed, since the half of the series winding connected to switch 1 reduces the effective coil voltage, the same amount that the half connected to 2 adds to the voltage up to that point. Since the potentials at the two points are the same they may be connected together. Continued rotation of the mechanism opens switches A and 1, and the voltage of the series transformer adds to the coil voltage of switch 2. As the regulator is rotated further, the voltage of the series transformer decreases to zero and the line voltage becomes equal to the coil voltage up to tap 2. Continued rotation repeats the process to the next tap as may be followed in detail from the sequence chart of switch operations, Fig. 10.

Any of the infinite positions of the induction regulator become operating positions so that an infinite number of steps in voltage may be obtained between the extreme tap position.

The step induction regulator is well adapted for use where bus or transmission circuit voltage is to be controlled over a large range in small steps and particularly when automatic control is desired. In this case automatic control merely calls for a voltage actuated relay with time delay, giving a much more simple control equipment than is possible with the step type equipment.

Separate Regulating Units

The tap changing equipments heretofore considered have been applied directly to the transformer unit. On



SEQUENCE OF OPERATION

SWITCHES	POSITION 1	2	3	4	5	6
A	+	+	+	+	+	
B		+	+	+	+	
1	+					
2		+				
3			+			
4				+		
5					+	
6						+

FIG. 10. DIAGRAM AND SEQUENCE CHART OF STEP INDUCTION REGULATOR METHOD OF TAP CHANGING

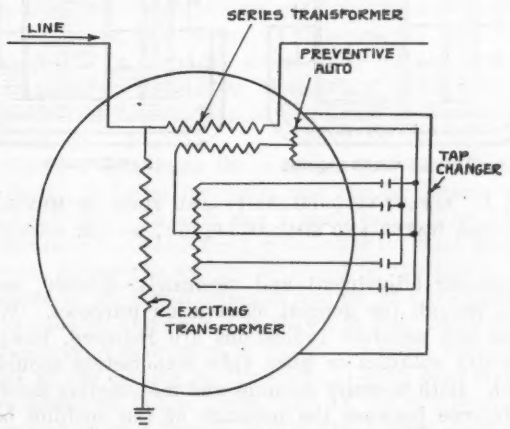


FIG. 11. DIAGRAM OF SEPARATE REGULATING UNIT

account of the fact that no additional transformer units are required, this generally gives the simplest, most efficient and most compact equipment to change the voltage. There are applications, however, where modifications of this simple arrangement are desirable.

In general, tap changing mechanisms are so far practicable for direct use in circuits up to 33,000 v., or carrying not more than 1200 amp. By using these units in the star connection of solidly grounded systems, it is possible to apply them to transformers of much higher voltage by placing the tap changer in the grounded end.

The use of a separate regulating unit may be desirable also from other consideration. For example, if it is desired to obtain voltage control with transformers

already installed, the separate regulating unit becomes very useful. In some cases the need for voltage regulation may not be permanent, so that a separate regulating unit may be used with the idea that it may later be transported to some other location.

The use of separate regulating units, however, is accompanied by the requirement of more floor space, lower overall efficiency on account of the extra transformers required, higher installation cost because of the interconnections, etc., required between the regulating unit and the main unit.

Figure 11 illustrates schematically the winding arrangement for a separate regulating unit. By suitably arranging the ratios of the respective series and exciting units, the tap changing equipment may be used to cover a wide range of applications. Both the series and exciting transformers may be mounted in the same case to reduce the number of bushings and simplify the connections and installation.

In the case of tap changing under load equipment designed to operate on high voltage ungrounded units, the auxiliary series and exciting winding may be built into the same unit to reduce the number of auxiliary windings and cores and increase the overall efficiency. The series transformer may be used as in Fig. 11, but the exciting transformers used in the separate regulating equipment may be replaced by a third winding in the main transformer as shown. This winding may be used for supplying an additional low voltage circuit if desired. A number of 10,000-kv.a., 140,000-v. delta connected units are now being built to change taps in the 140,000-v. winding by this method.

Measuring with the Barometer and Manometer†

MANIPULATION OF INSTRUMENTS, PRINCIPLE OF CAPILLARITY, FORMATION OF MENISCUS AND NECESSARY PRECAUTIONS. BY S. A. CURRY*

FOR THE MEASUREMENT of vacua and pressures of but a few pounds above atmospheric, the Bourdon spring type of gage, discussed in a previous article, is often used and when of a suitable type and range, kept

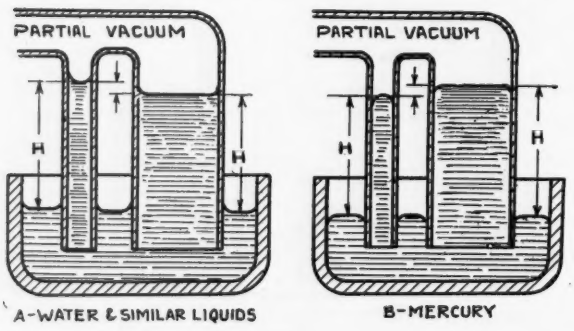


FIG. 1. EFFECT OF CAPILLARITY AND FORM OF MENISCUS: A—FOR WATER AND SIMILAR LIQUIDS, B—FOR MERCURY

in proper adjustment and accurately checked, serves well enough for general observation purposes. When close and accurate indications are required, however, mercury columns or glass tube manometers should be used. Both mercury columns and manometers show the difference between the pressure of the medium being measured and that of the surrounding atmosphere. Since the value of the indications of these instruments is affected by the atmospheric pressures, it is necessary to obtain the latter accurately with barometers and to apply the atmospheric pressure at the location of the instrument, otherwise the readings of the instruments are meaningless.

As is well known, atmospheric pressures vary with various elevations, weather conditions and the like, so it is customary, for standardization purposes, to refer barometer readings to a standard atmospheric pressure or its equivalent. This standard is the equivalent of the pressure per square inch exerted by a column of pure mercury at a temperature of 32 deg. F., 29.92 in. in height, at the sea level at 45 deg. latitude, which corresponds to 14,691 lb. per sq. in. absolute pressure. It is common practice to refer the vacua of condensers and such equipment to a 30-in. barometer, instead of the above standard of 29.92 in., the temperature of a 30-in. mercurial column corresponding to the foregoing standard being 58.4 deg. F.

THE ANEROID BAROMETER

The aneroid barometer is a common type of barometer, but as a general rule, is not very dependable for accurate indications. This is the type, usually of an inferior grade, that you have hanging at your back door to forecast the weather conditions. The aneroid barometer depends upon the compression of a metal diaphragm by the atmosphere which actuates the dial pointer.

On account of its mechanical construction and metallic diaphragms, it is likely to get out of order, requiring almost constant checking to be assured it is correct; it is also subject to temperature errors. It is not to be recommended for obtaining close and accurate barometric indications.

THE MERCURY BAROMETER

The mercurial barometer is the preferable type; this consists of a glass tube closed and sealed at one end with the other end open and submerged in a pool of mercury exposed to the pressure of the atmosphere. The internal upper end of the tube must be a perfect vacuum, so that the height of the suspended column of mercury in the tube above the top surface of the mercury in the pool at the bottom is balanced by and equivalent to the atmospheric pressure, measured in inches of mercury.

Differences in elevation, weather conditions, temperatures and so on are usually the main factors for which corrections are required, assuming good grades of barometers and that they are in proper condition. Authentic corrections for elevation, latitude, temperature of the mercury column, capillarity of the tube

*South Philadelphia Works, Westinghouse Electric & Mfg. Co.

†This is one of a series of articles by Mr. Curry presenting some interesting facts about several common types of power plant instruments. An article discussing pressure gages appeared in the May 15 issue.

(sometimes capillarity is compensated for by the barometric scale), and the like, may be obtained from standard hand-books, F. O. Ellenwood's steam charts, Smithsonian physical tables and other publications issued by the Government Printing Office at Washington, D. C., and various other sources.

Mercurial barometers are sometimes subject to a slow leakage of air into the vacuum space above the top of the mercury column, which affects the accuracy of the instruments. They should be checked periodically with the local or nearest U. S. Weather Bureau Office, where accurate barometers are maintained, care being taken to determine and apply the necessary corrections for all variations in the foregoing factors where they differ from those existing at the U. S. Weather Bureau.

Mercurial barometers are not considered as portable instruments. They must be handled very carefully and should be carried in an inverted position when it is necessary to move them about, care being taken to invert them slowly and gradually. They should be permanently installed:

1. Where they will be free from vibration, air currents, variations in temperature, etc. They should not be located directly in the sunlight or have an electric light in close proximity that will cause heating.
2. Hanging freely so that the mercury column is vertical.
3. In a good light where they can be easily read, giving attention to being able to set the zero level accurately as well as read the top of the column.

When reading a mercurial barometer, the zero should always be set and then the upper slide adjusted to the top of the mercury column. The zero is set by lowering the mercury in the lower basin and then carefully raising it until the tip of the ivory pointer touches but does not enter the mercury so much as to cause a dimple. If the top surface of the mercury is clear, the coming together of the tip of the pointer and the pointer reflection in the mercury will assist in giving the proper setting. The upper slide, starting from a point above the top of the mercury column, is then lowered until it is in line with the top of the meniscus, or when the ray of light between the slide and top of meniscus disappears. A white paper placed back of the column both at top and bottom materially assists accurate settings.

Capillarity and Meniscus of Liquid Columns in Glass Tubes

Reference has been made to corrections for capillarity and to the meniscus of the column of mercury of mercurial barometers; as these two features enter also into our consideration of mercury columns and U-tubes using both mercury and other liquids, a brief treatment of these two items may be helpful. There is often some diversity of opinion regarding what part of the meniscus should be used when reading the height of a liquid column, which the following may clarify.

The surface of any liquid is in a state of tension, due to the forces of cohesion of its particles similar to a membrane stretched equally in all directions and is dependent upon the nature of the liquid, its temperature and other conditions but not on the form of the body of the liquid. Capillarity is the resultant of the forces of cohesion of the liquid particles and the forces of adhesion between the particles of the liquid and the surface of any adjacent substance. For most liquids this resultant is an attraction causing portions of the liquid, where in contact with another substance, to rise above the general level of the liquid. But for mercury this resultant takes the form of a repulsion causing a depression of the portion of mercury in contact with another substance. The capillarity resultant depends not only on the nature of the liquid, temperatures, etc., but also on the nature of the adjacent substance both as to material and condition of its surface. It would make a difference in the capillarity of a mercury column in a glass tube if the tube were dirty or greasy instead of dry and clean; the smoothness of the bore would also have some influence.

Taking the case of liquids in glass tubes, as experienced with such instruments as we have under consideration, first considering the liquids for which capillarity forms an attraction, such as water, etc., then mercury, we would find the following conditions:

The phenomenon of capillarity causes the particles of water adjacent to the surface of the tube to rise or climb up the inside wall, which is resisted by the surface tension of the liquid and by gravity, until equilibrium is established, limiting the extent of the rise and determining the shape of the adjacent and the nearby liquid to the walls of the tube. Picture the top surface of water as being a membrane or a blanket, with the capillarity forces acting on its entire periphery, trying to lift it as in Fig. 1A.

With mercury a similar performance takes place excepting the capillarity phenomena causes a depression of the particles of mercury adjacent to the walls of the glass tube, the "surface tension" resisting and gravity assisting in the depression. In this case our membrane or blanket is being pulled down at its periphery, tending to compress the column of mercury. The shape or outline of the top surface of the liquid is termed the meniscus.

Figure 1 illustrates the meniscus and the effect of capillarity, A being for water and similar liquids and B for mercury. In each case a small and a large tube. are illustrated, each assumed to be under the same partial vacuum, lifting the column of liquid in the tubes. In A, wherever the liquid comes in contact with the surface of the tube or container it is shown to rise, while in B, for mercury, a depression is shown. H is the measured height of the column in the tubes in each case and is to be measured to the lowest part of the meniscus for water and similar liquids and to the highest part for mercury.

It will be noticed that the height of the column in the small tubes is slightly higher in A for water, etc., and lower in B for mercury, than in the large tubes, though both columns are assumed to be acted upon by the same vacuum. This is to illustrate the fact that capillarity tends to raise the column beyond the true static head for water and similar liquids, and to depress it for mercury, when the bore of the tube is small, and is not effective in this respect when the tube bore is increased beyond a certain size for a given set of conditions.

When the tube bore is small enough to permit the capillarity to cause a rise or depression from the true height, corrections to height of column are necessary.

The following table, taken from the Smithsonian physical tables, shows the corrections to be applied for capillarity for mercury. It will be noticed that the amount of correction increases as the size of the tube is decreased, and as the height of meniscus increases.

CAPILLARITY CORRECTIONS FOR MERCURY IN GLASS TUBES

Bore of tube in inches	Height of Meniscus in Inches							
	.01	.02	.03	.04	.05	.06	.07	.08
	(Corrections in inches to be added to the observed readings.)							
0.15	.0236	.047	.0686	.0923	.1156	.....	.....	.....
0.20	.011	.023	.0328	.0454	.0594	.0785	.....	.....
0.25	.0055	.012	.0192	.0276	.0368	.0472	.0588	.....
0.30	.0036	.0079	.0126	.0177	.023	.0288	.0348	.042
0.35	.....	.0051	.0082	.0115	.0149	.0185	.0224	.0265
0.40	.....	.0040	.0061	.0081	.0102	.0122	.0142	.0162
0.45	.....	.....	.0032	.0051	.0068	.0083	.0096	.0115
0.50	.....	.....	.002	.0035	.0047	.0056	.0064	.0071
0.55	.....	.....	.0008	.002	.0031	.004	.0047	.0052

MERCURY COLUMNS AND MANOMETERS

Mercury columns and manometers or U-tubes are similar in principle, differing only in their construction.

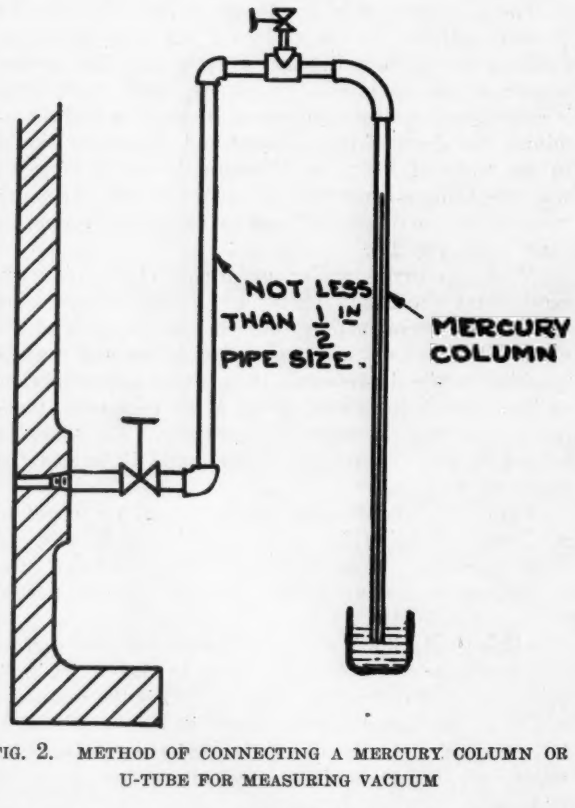


FIG. 2. METHOD OF CONNECTING A MERCURY COLUMN OR U-TUBE FOR MEASURING VACUUM

The mercury column consists of a glass tube, the upper end connected to the source of vacuum and the lower end submerged in a pool of mercury exposed to atmospheric pressure. The difference in level from the top of the suspended column to the top of the mercury in the pool represents in inches of mercury the difference between the pressure in the vessel and that of the atmosphere at the location of the mercury column. The manometer or U-tube is a glass tube, bent in U form, one end connected to the source of vacuum or pressure, and the other end open to the atmospheric pressure. Mercury, water or other suitable liquids may be used under certain conditions and the difference in levels between the two columns represents in inches of the liquid the difference between the pressure in the vessel and the atmospheric pressure at the location of the manometer. The manometer has an advantage over the mercury column in that it can be used for measuring pressures both above and below that of atmospheric within the limits of the length of the glass tube.

As previously stated, it is customary when referring to the vacuum in a condenser or steam turbine, to refer it to a 30-in. barometer for standardization purposes. This is done by finding the difference between the 30-in. barometer and the corrected barometric pressure in inches of mercury at the location of the mercury column, subtracting or adding this difference to the vacuum measured by the mercury column, when the barometric pressure is respectively more or less than 30 in. For instance, if the mercury column read 28.4 in. and the barometer corrected was 29.4 in., then, adding 0.6 in., the difference from 30 in., gives 29.0 in. vacuum referred to a 30-in. barometer. Or, if the barometer read 30.2 in., we would subtract 0.2, giving 28.2 in. vacuum referred to a 30-in. barometer.

For close accuracy, the readings of the mercury columns and the barometer should be corrected to the same temperature, viz., 58.4 deg. for 30-in. barometer. The mercury column should also be corrected for tube capillarity, when small bore tubes are used, in accordance with the table for capillarity corrections shown above.

On account of the capillarity or depression being the same in both legs of a U-tube, no correction for capillarity is necessary, provided both legs are uniformly the same diameter and clean.

Care must be exercised in making the piping connections for mercury columns and U-tubes to insure that moisture and liquids are not entrapped and held in suspension; these, due to their weight, may cause errors of considerable magnitude. Small pipes or tubes will, on account of their capillarity, hold in suspension moisture or water which will cause errors at the rate of approximately 0.036 lb. for each inch of height of the water.

Pipe connections should not be less than ½-in. pipe size and should be arranged to slope back and drain from the instrument to the source of vacuum without any pockets, as illustrated in Fig. 2, so that there will not be any tendency for moisture to collect. A tee with a valve in the branch outlet should be provided close to the mercury column so that, by opening the valve, air may be admitted at suitable intervals to insure the pipe being kept free from moisture.

Care must be taken to see that no air leaks exist in the pipe connections to the instrument. This can readily be determined by having a valve in the line close to the source of vacuum, putting vacuum on the instrument to get the column of mercury suspended, then closing the valve. If there are no leaks, the mercury column will remain in suspension or, if the leak is very slight, it will be extremely slow in dropping.

Velocity of flow of the medium being measured past the opening of the pipe connection to the instrument is liable to cause errors. Care should be taken to have the instrument pipe connection opening flush and at right angles with the inside of the wall of the condenser, pipe or vessel through which flows the medium being measured.

Materials Limit Boiler Operating Conditions*

ANALYSIS SHOWS THAT NICKEL-CHROMIUM ALLOYS OFFER THE SAME TEMPERATURE SAFETY MARGIN AT 1500 LB. OR 900 DEG. F. THAT ORDINARY CARBON STEEL DOES FOR 250 LB. OR 400 DEG. F. BY A. L. MELLANBY AND WILLIAM KERR

IN ALL ATTEMPTS to reach extreme pressure and temperatures the problem of materials exercises a controlling influence. It represents the main factor limiting the boundaries of ultimate achievement, and the main difficulty restricting advance. Higher pressures and superheats, through stress action and the weakening influence of temperature, increase the severity of the conditions inflicted on the materials in a sort of double progression. Boilers and turbines are concerned, in a differing degree; and it is essential to appreciate how the strength and usefulness of metals are affected, if any genuine estimate of the difficulties of advance is to be formed.

Quality of the resistance offered by a material to corrosive and erosive influences will always arise in steam plant applications. Whatever degree of excellence this resistance may attain under moderate conditions of working must be maintained at the higher values. This aspect of the subject of materials raises wide issues not capable of reasonable treatment here but it is fairly clear that the steady development of modern materials can meet the requirements satisfactorily. Corrosion is not purely an effect of higher steam pressure. It is present and troublesome to some extent in normal conditions and the natural tendency to greater care in the elimination of impurities and occluded gases in the feed water will probably reduce the difficulties to reasonable limits even at higher temperatures.

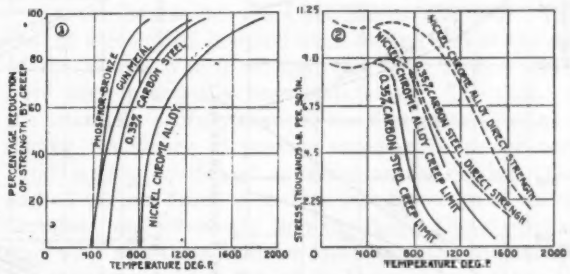
STEAM DISSOCIATION MAY PLACE A DEFINITE LIMIT

One side of this matter might be referred to in passing, as it is not fully appreciated. A hot boiler tube above a certain temperature produces some slight dissociation of the steam with evolution of free hydrogen and presumably oxidation of the metal. The effect is just of reasonable magnitude at or above a metal temperature of 900 deg. F. with ordinary boiler tubes, and increases rapidly thereafter. If this should prove fundamental and general with all metals, a limitation of some moment is introduced; but it is perhaps probable that special materials will delay the critical condition.

Reduced strength of metals at high temperatures is, however, the primary and most definite effect to be considered and in this connection the notable work of recent years on the phenomena of "creep" takes on a special significance. It provides, as it were, a new and more stringent basis for judgment of the applicability of metals in the higher temperature ranges, and certainly displaces the strength figures, commonly determined by direct test, as the criterion of value.

Metal subject to stress over a period of time at a temperature above some moderate and characteristic limit will fail, by creep, at a much lower stress than that indicated by a straightforward break after heating. For any temperature the stress causing ultimate fracture depends on the time but a limit is finally reached below which failure will not occur. This is the "creep limit" for the metal at the temperature of investigation; and when determined for a series of values the creep limit curve is obtained. This curve must take the place of the usual strength temperature diagram.

Thus, taking the direct strength under a quick break at any temperature as the basis figure for that temperature, Fig. 1 shows the percentage reduction of this apparent strength by creep effects, for a few different materials. Figure 2 shows, in another way, the relation between the direct strength and creep limit curves for the carbon steel and the nickel-chromium alloy of Fig. 1, the former representing the effect for an ordinary material and the latter displaying the highest creep limits that have so far been reached. The general order of creep effects and the type of relationship between creep



FIGS. 1 AND 2. FOR HIGHER TEMPERATURES THE CREEP LIMIT RATHER THAN DIRECT STRENGTH CURVES MUST BE USED

limit and direct strength curves are fairly similar for different metals. It will be appreciated from these diagrams that the effect is quite extraordinary. In view of it, non-ferrous materials of the brass or bronze type practically cease to have any real value in the high temperature field.

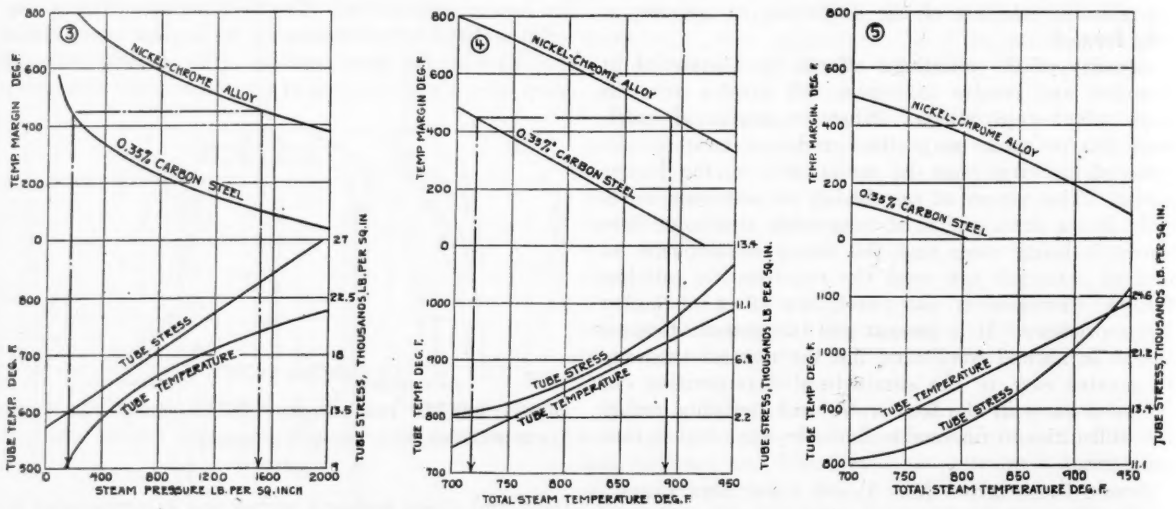
Consequences of the fact of creep failure simply amount to the degeneration of what is commonly understood as a factor of safety, on a stress basis, into a mere margin of safety on a temperature basis. Thus the carbon steel of Fig. 1 if subject to stress of, say 16,000 lb. per sq. in. at 900 deg. F., would have an apparently ample factor of safety as based on direct strength, but would have no real margin of safety on temperature considerations. While, in general, the first method of judgment might be as good as the other when it was certain that the temperature value would not be exceeded, it ceases to have any merits when, as in boilers, the metal temperatures are not necessarily confined within narrow limits.

Tubular furnace walls receive heat by direct radiation. There is little real knowledge of the magnitude of this effect; but it appears to be reasonable to assume that the total heat received is a proportion of the total furnace heat depending on the ratio of the heat developed to the absorbing surface presented. No matter how the tubes receive their heat externally, the transmission of this heat to the fluid within is by convection and a rough estimate of the order of the wall tempera-

*From a paper read before the Institution of Mechanical Engineers.

ture may be made by convection methods. The metal wall temperature in this case provides no real basis of judgment. It is the temperature margin on the creep limit that should be employed, and for this the stresses are required. Taking a tube 4 in. in external diameter and ¼ in. thick, as used in the Hell Gate Station, the stresses are as shown in Fig. 3. By means of the wall temperatures and stresses so obtained and the creep limit data of Fig. 2, it is possible to determine the temperature margins shown by the upper curves.

It will be observed that at the highest pressures the security, in the case of ordinary steel, has practically vanished, and that to obtain the same margin of safety as this material provides at the lowest pressure would necessitate the employment of special metals. It should also be remarked that the use of fins on these tubes may



FIGS. 3, 4 AND 5. TEMPERATURE-STRESS EFFECTS IN WATER COOLED WALLS, CONVECTION SUPERHEATERS AND RADIANT SUPERHEATERS CAN BE COMBINED WITH CREEP LIMIT CURVES TO FIND THE TEMPERATURE MARGIN

easily produce high local temperatures and stresses that would render the margins displayed in Fig. 3 rather generous in their allowance.

Convection and Radiant Superheaters Must Be Considered

In the boiler the lowest tube rows are in much the same condition as the side walls but the superheater tubes above the first boiler section deserve a little consideration. The heat transmission here is purely by convection processes. With tubes 2 in. in external diameter and 0.15 in. thick, the stresses shown in Fig. 4 are obtained. In this procedure, pressure and total temperature have been allowed to progress together in such a manner that the superheat is practically the same at all pressures.

For radiant superheaters the procedure would be a combination of the two cases already studied for, if it be assumed that the radiation per square foot is the same in such an arrangement as has been taken for the side walls, several issues are raised. Tube temperatures and temperature margin curves are shown in Fig. 5. It is obvious that the employment of this type of element would be seriously restricted by pressure and temperature advances, and it may be presumed that this limitation will affect its use with ordinary boilers at high total steam temperatures.

Preheaters Cause No Temperature Difficulties

Air preheater tubes are not subject to any severe stress action and the wall temperatures will not be high except in the event of considerable advance in combustion air temperatures. It is sufficient to notice that the tube temperature in such cases is practically the mean of the air and gas temperatures, owing to the similarity of the fluids and their conditions of flow on the two sides of the tube wall.

It should be clear that the steam temperature limit is not a value capable of indefinite growth; and the stable nature of present-day temperature values in face of movements in all other directions clearly demonstrates the difficulties in this connection. Assuming that 250 lb. per sq. in. and 700 deg F. steam pressure and temperature are perfectly safe with ordinary steels; and, also, that the nickel-chromium alloy results provide an indication of the qualities that higher orders of materials possess, reference to Fig. 3 for the metal temperatures of the radiant heat surface will show that the stated pressure gives a margin of 400 deg. F. on ordinary steel. Carrying this along to the nickel-chromium line on the same diagram it will be observed that the same margin is offered by the better material at 1500 lb.

Roughly 1500 Lb. and 900 Deg. F. Form the Upper Limits

Again, on Fig. 4, for the superheater tubes, the same temperature margin of 400 deg. F. shows 900 deg. F. as a steam temperature. Hence, the materials data, as evolved from the previous studies, provide the rough ideas of 1500 lb. per sq. in. and 900 deg. F. as limits possible by the employment of special materials, offering the same security as ordinary steel now provides.

One characteristic feature of the radiant heat boiler surface conditions is the slow reduction of the margins by pressure. The corresponding feature of the superheater surface is the rapid reduction by steam tempera-

ture. If it should be allowed that ordinary steel is amply safe at 500 lb. per sq. in., 750 deg. F., the permissible margin reduces to 300 deg. F., and 2000 lb. per sq. in., 950 deg. F., appears as acceptable for the better material. The narrow change in the temperature level is notable.

In the method just followed relative values alone are employed and an important point of view is attained by a simple procedure. It is, however, hardly possible to imagine that, at the higher temperatures, even with better materials, the same margin will be sufficient; and it is not desirable to believe too readily that advance, even on the assumption that still better materials can be developed, will not be impeded by special difficulties such as steam dissociation on the tube wall or excessive initial distortion. In the past authors have expressed their conviction that 900 deg. F. represents the probable maximum operating temperature for the steam plant; and they see no reason to depart from that opinion.

High Speed Refrigerating Compressors*

EUROPE'S SLENDER RESOURCES COMPARED TO THOSE OF UNITED STATES RESPONSIBLE FOR DEVELOPMENT OF HIGH SPEED COMPRESSORS. BY J. C. GOOSMANN

ECONOMICAL NECESSITIES in Europe have always emphasized the importance of obtaining the utmost from any material, whether coal, iron, lumber, etc., on account of its much greater relative cost when compared with American resources. Any manufactured product containing more material than required represents under such conditions a costly example of waste. In and during the process of manufacture conservation of energy, of heat, of light and of power always has to be carefully husbanded, exchanged and protected against dissipation.

Necessity, as always, is the mother of invention and the great need for economy brought forth the development of high pressure, as well as high temperature (superheated) steam as a distinct European achievement, dictated in the first place by the high price of steam coal and resulting in the means of getting the greatest heat value out of it. High tension and high frequency current, which is now in universal use, had its incentive in the high cost of conducting material required for transmitting electricity of lower potential. A survey over the entire field of industrial, civic and commercial endeavor shows the same careful regard to economy in the material coupled with the highest efficiency of the product. Volumes were reduced everywhere with pressures and potentials on the persistent upgrade as a matter of consequence.

In steam engine practice high speed poppet valve machines were always used, long before we in our country found it advisable to abandon the slow running Corliss engine type in favor of more economical units, because with coal at a low price and every other material in abundance, we never felt the necessity nor the economy of saving in bulk as well as in quality by substituting higher priced but also vastly more complicated equipment and enjoyed the fullness of our country's resources to our hearts' content.

It is not so many years ago, to be more definite, 20 to 30 yr., that good steaming coal was quoted in the Chicago market at a dollar per ton at the mines with a dollar added for freight. While it is true that in ordinary plants with horizontal tubular boilers it was necessary to burn not less than 3 lb. of coal per boiler horsepower, it will be seen that $2.00 worth of coal produced 660 boiler horsepower, that is the coal cost remained at the low figure of 0.3 cent per boiler horsepower. The European coal consumption was even at that time as low as 0.5 lb. of coal, but even so in comparison with our low coal price hardly justified the substitution of high priced equipment for the sake of the reduction of fuel quantity as long as the latter remained at a low cost level.

In the course of years conditions changed. This change accelerated in speed until during and at the end of the World War it reached top notch figures which have since practically been maintained. The dawn of the twentieth century marked the first attempt of producing machinery of greater economy in power cost. Producer gas equipment appeared on the market. Gas and oil engines found their way into the shops of manufacturers and ultimately into the field. Diesel engines gradually won their fight for supremacy and the uniflow steam engine produced a marked step forward in coal and steam economy as well as in power efficiency.

The World War brought, among the few good things in its train, the first stern realization on this continent of our past extravagance and waste with a firm resolve to cast it aside and adopt in its stead a sound policy of avoiding it in any form.

HIGH TURNING SPEEDS FIND FAVOR IN EUROPE

Europe came along with higher turning speeds of engines and particularly refrigerating machinery as early and even prior to 1910. High speed compressors were developed and in evidence everywhere throughout central Europe including Switzerland, which is really the cradle of ammonia refrigerating compressors.

Richard Stetefeld of Berlin, Germany, pointed out in his book on Ice and Refrigerating Compressors, published before 1907, a series of high speed compressor tests with complete performance figures as well as tables of dimensions, comprising SO_2, NH_3 and CO_2 machines, concluding with the statement that the efficiencies of these machines together with the economical advantage of much reduced masses entitled them to preferred consideration, although at that time slower running machines were considered slightly more efficient. The relative speeds of these machines were then from 300 to 450 r.p.m.

M. Hirsch in his book "Die Kaltemaschine," published in 1924, analyzes the advantages of higher turning speeds as follows:

"A long stroke machine has the disadvantage of large surfaces which must be considered a deterioration of the favorable relation between bore and stroke. The reduced turning speed at a long stroke with constant

piston speeds increases the time element for compression and discharge periods, which in turn increases the undesirable effect of unduly large surfaces. Hence the rule at fixed diameter of bore and constant piston speed should be a short stroke and increased turning speed. His general recommendation favors L = d, or square dimensions from which he would deviate only in the case where the valves are placed in the cylinder head, rather than below the head in the cylinder proper. According to Hirsch turning speeds are limited only by the consideration of inertia control in reciprocating machines in connection with the power thrusts reflected upon the shaft at the moment of reversal in the direction of piston movement."

It is necessary, however, to point out in this connection that square dimensions when applied to carbon dioxide machines have the unfavorable characteristic of calling for unusually large pin and bearing sizes. The most favorable relation of the stroke to bore in these machines seems to be d × 1.3, when d represents the cylinder bore.

The latest construction of machines built by Freundlich, Niemeyer and others, ammonia as well as carbon dioxide, favor high turning speeds without exception for steam as well as for direct motor coupling.

For piston speeds and their limit, tables have been prepared with a ratio somewhat smaller for small machines as compared with those larger in capacity.

Freundlich uses accumulators, or liquid traps in connection with ammonia compressors and employs a small liquid pump with a tandem piston to discharge the liquid into the evaporator.

In England high speed machines are of a more recent development. Practically all of the latest English enclosed crank case machines are patterned after standard American practice, especially those of the NH_3 type, with the exception that the West Company uses compressor valves of the sleeve type, which is of more than passing interest since the investigation of compressor valves, whether or not the poppet, plate, ribbon or feather valve is the best, is by no means completed. On the whole the poppet valve holds its well merited position for reliability and faithfulness in service.

A decided novelty of a crank case CO_2 compressor construction is that of the H. J. West and Co. in which the entire crank case is tooled out of a solid block of steel. That sort of a design is hard to swallow for us on this side of the Atlantic. Our labor cost alone would prohibit it. What is the matter with English metallurgy and foundry practice? Thirty years ago European metallurgy and foundry practice seemed to be way ahead of ours; in fact, we had no foundry science, but we surely have it today. Our foundries are competent to furnish any desired casting, gray iron, air furnace iron, semi-steel, malleable for any strength, toughness, tightness and ductility.

In 1905 Fred Wittenmeier, then with the Kroeschell Bros. Ice Machine Co., adopted open hearth steel blocks for his cylinders, but it had many disadvantages of which the labor cost certainly was not the smallest and has since been abandoned.

The writer has used close grain iron casting since 1903 and those of so-called semi-steel exclusively since 1907 for all high pressure parts of CO_2 machines and equipment, such as cylinders, valves, fittings, separators, liquid receivers and condenser parts.

Thus it is of considerable interest to watch not only the competitive and progressive efforts in our own country, but those in other lands as well.

This is the time and age of the interchange of ideas, designs and practices free from the shackles of competitive narrowness, jealousies and rivalries. We have successfully overcome and discarded such handicaps. Our progress is enhanced and accelerated by united efforts, which is making our work immensely more pleasant and our advancement exceedingly rapid.

Unit Mill System Favored for Cahokia

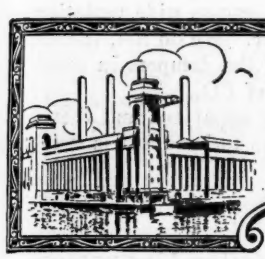
CAREFUL STUDIES of the comparative first cost and operating economies of the unit versus the storage system of pulverized coal made at Cahokia station was summarized by E. H. Tenney of the Union Electric Lt. & Power Co. in a discussion before the Kansas City A. S. M. E. Regional Meeting. He stated that these studies had resulted in the adoption of the unit system for three 1801-hp. boilers now about to be erected in a certain section of Cahokia. Two 1500-lb. per hr. mills per boiler will deliver coal to four horizontal forced draft turbulent burners, supplied with preheated air.

Furnace walls are to be of recessed water tube and refractory type and there will be no water screens. Iron shrouded water wall construction will be used for the rear wall, ash pit and front wall arch above the boilers.

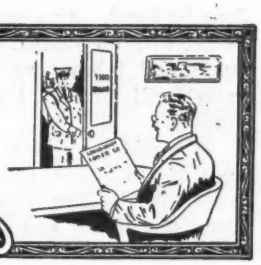
Based on experiences with both systems at St. Louis, he stated that the two systems may both be successfully used with Midwestern coals, but that the unit system offers special advantages in lower investment costs, due to elimination of storage bins, dryers, separators and transport systems, gives equal furnace efficiencies with less operating and maintenance labor, increases simplicity of installation and is also cleaner, quieter and probably more safe to operate.

At Cahokia, problems of preparation and transportation have been solved, although the maintenance cost on this equipment still comprises about ¼ of the station total. Erosion of side wall refractories has been eliminated only by the use of water cooled walls. The fin tube type is satisfactory, except that it is difficult to avoid carbon loss and smoke at reduced ratings and water tubes recessed in brick has proved to be the most satisfactory type. Experience has demonstrated that there is great advantage in supplying larger percentages of combustion air at or in the burner, and giving the air and fuel mixture sufficient turbulence to cause early and complete ignition. This results in lifting the hot zone away from the ash pit and eliminating in complete combustion in the furnace and the formation of slag.

Horizontal burners admitting more air with the fuel were installed at the Ashley St. Station about a year ago, resulting in increasing the steaming capacity of each boiler about 50 per cent and raising the combined boiler and economizer efficiency from a previous 70 to a present 82 per cent, with smokeless combustion and without slag in the ashpit.



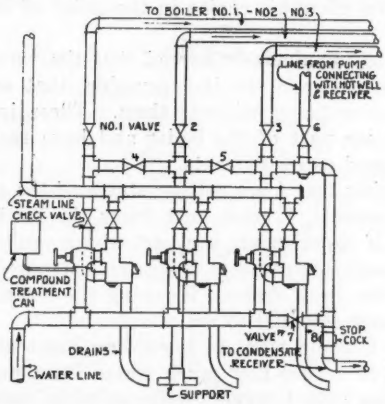
LETTERS DIRECT FROM THE PLANT



Flexible Control of Boiler Feeding

OUR PLANT now has two 6 by 4 by 6 duplex pumps that have been in operation about 19 yr. They are too small for the work now required of them, especially during peak loads, so a new motor driven centrifugal pump has been ordered to replace them.

Heretofore only one injector has been used for all of our boilers. We have now installed an injector for



SHOWING ARRANGEMENT THAT PERMITS ANY ONE BOILER TO BE SERVED BY ANY ONE INJECTOR OR BY FEED PUMP

each boiler, piping it in such a way that any one injector can serve any one or more of the three boilers as shown in the accompanying illustration. The space in which the piping was installed was limited, being only 4 ft. long and 8 ft. high. It was located at the water supply which was alongside of boiler No. 3.

All fittings and piping used on lines leading towards the boilers are extra heavy. Each boiler has a check valve and angle valve in addition to what is shown in the drawing. These precautions avoided hammering when starting the injector as No. 1 boiler is located about 38 ft. from the injectors.

As much as possible of the injector sections were assembled before time in order that no time would be lost when the actual installation was to be made. By this means the actual time of installation, including the dismantling of the old injector and piping, was only about 3½ hr. During the placing of the injector, water was held in the boilers at about 2½ gages so as to provide against an emergency should anything, such as the pumps, fail to operate properly.

When this arrangement of injectors was planned, provision was made to supply the boilers with water at the front as well as at the rear.

As shown in the illustration, valves 1, 2 and 3 regulate the supply to the respective boilers. The two by-pass valves 4 and 5 will permit any injector to serve any of the boilers. Supposing No. 1 injector to be out of commission; in order to supply No. 1 boiler with water, all valves except 1 and 4 should be closed. This would permit No. 2 injector to be used. The line with valve 6 comes from the feed pumps. It could also be used to serve the boilers with water. If the pump is used for this purpose, the water is not heated because the heater is not connected with this line.

At the bottom of the drawing, valve 7 is shown in the cold water line. By operating the proper valve we can fill any boiler with cold water for inspection test or for firing up without using an injector.

Connection to the condensate receiver is made through the line in which stop cock 8 is located. This receiver is cleaned every week. We use the injector to fill this receiver and thereby have hot water at once instead of filling it with cold water and waiting until it has become heated by the hot water from the traps, etc.

Regarding water treatment, until recently we had been putting the compound directly into the condensate receiver but we found by experience that all three boilers were not treated alike, so we now treat each boiler separately. Starting the injector, after it has been properly connected with the boiler which is to be served, the valve at the compound can is opened and an amount of compound sufficient to meet the need of the boiler being treated is permitted to be gradually fed to the boiler.

All of the valves are operated by means of 6-in. long iron handles which were substituted for the usual hand wheels in order to increase the ease of operating the valves and avoid the use of wrenches to assist opening and therefore, due to this cause, valve stems are no longer broken.

San Leandro, Calif. RAYMOND A. DASKA.

Flexible Metallic Gaskets Better for Large Pipes than Those of Rubber

JAMES E. NOBLE'S letter on Inserting Large Thin Gaskets, published in the May 1 number of Power Plant Engineering, is interesting because it so ably explains why we should not buy gaskets because of low price. He begins his article with these words: "Because of its low price, a roll of $\frac{1}{32}$-in. sheet rubber packing was purchased by the manager of our power plant."

Then, as a result of having purchased this low priced rubber packing, Mr. Noble had no end of trouble trying to insert the packing between flanges. I wonder how much the trouble cost altogether. As I understand it, he manufactured a special gasket out of several large thin rubber gaskets using stiff wrapping paper between the gaskets; and so forth; an expensive process when

done by hand. As a result, he obtained a thick rubber gasket with unsatisfactory wrapping paper between the layers and I have every reason to believe that such a gasket will not last long because rubber itself is not durable.

It would have been far more sensible for the manager of the power plant to have spent a little more money in the first place for a flexible metallic gasket made of asbestos and steel or even asbestos and monel metal. Gaskets of that type are stiff enough for insertion into a 14-in. line without any trouble. In fact, gaskets of this kind give no trouble when being inserted in pipe lines twice or three times as large as 14 in. It is merely necessary to remove the bolts halfway around the flange, pry the flanges apart and insert the gasket. No time is wasted.

Also, Mr. Noble says that he found it necessary to scrape the face of the flanges till they were clean before inserting the gasket. Scraping is also unnecessary when the correct gasket is used. A first-class flexible metallic gasket will come out without leaving any residue on the faces of the flanges to be scraped off. What is more, a first-class flexible metallic gasket can be used over and over many times while a rubber gasket can usually be used only once. A first-class flexible metallic gasket also resists much higher pressure than a rubber gasket. I know of tests that were carried up to 1000 lb. per sq. in. on a flexible metallic gasket without any leakage whatever and the gasket wasn't even screwed up as tight as would be necessary with a rubber gasket.

Newark, N. J. W. F. SCHAPHORST.

Human Factor Most Important in Boiler Operation

MANY ARTICLES have been written on operating power plants efficiently. When efficiency is mentioned we are likely to think only of draft gages, CO_2 recorders, patent furnaces and automatic devices of various kinds. As a matter of fact, a plant may be fully equipped with the most up-to-date apparatus that can be purchased and still fail to attain a high degree of efficiency in operation.

Efficient operation cannot be expected unless the personnel of the plant is active, capable and willing to do everything possible to see that every apparatus and device in the plant is properly handled and that proper methods are used to secure not only proper records but proper analysis of such records in order to know not only how the plant is performing but also how to better present performance, if possible.

In one plant where a CO_2 recorder had been installed, the claim was advanced that, as the percentage of CO_2 is to a considerable extent influenced by the draft, a draft recorder should be installed with a CO_2 recorder. Such a combination will show the amount of draft maintained at the time the corresponding CO_2 formed is recorded. A study of the charts under different conditions will indicate the proper position in which to place the damper.

Draft through the fuel bed depends upon the amount of air passing which is affected by the resistance of the fuel bed. Were this resistance constant, the amount of air used and the percentage of CO_2 formed would always be solely dependent upon the draft. But the depth of fuel and of ash, etc., causes wide variation in the resistance to the flow of air. We do not, therefore, have an exact rule for setting the dampers in order to obtain the highest percentage of CO_2.

To buy expensive efficiency apparatus and then employ cheap, inefficient operators to handle it is surely a poor business proposition.

Toronto, Canada. EDWARD JAMES.

Instruments Aid Boiler Operation

UNDER THE above title, Mr. Adams, in the issue of May 1, brings up a problem that has probably puzzled every boiler executive, "What instruments to buy?"

It is now universally agreed that instruments have passed from the luxury to the necessity stage and that the plant without them is a back-number.

Since only the largest boiler plants can afford to buy all the instruments advertised, the average industrial boiler superintendent has to choose the few allotted. Mr. Adams gives his choice in the order of importance to him.

It is so unanimously agreed that the water column and pressure gage are indispensable, that one cannot buy a boiler today without them. These instruments have become part of the boiler and have really ceased to be classed as instruments.

Knowing that I am getting steam of the right pressure to operate, I must next know the kind of steam put out, if superheaters are part of my equipment. So that a steam temperature indicator, or recorder preferably, is my next choice. Knowing the steam temperature is most essential to me.

Next I would want to know how much steam I am making; or rather how much water I am putting into the boilers. So I would desire suitable water meters. The cost department soon tells me how much coal I have used at the end of the month, as they buy it by the ton; so that with the water metered, I can establish costs. It also gives me my ratings, load, etc.

Most industrial plants have scale trouble, which without proper treatment, becomes very serious, so that I want to know what my water contains; and I next would demand water analysis apparatus.

I believe that the above-mentioned instruments are essential to continuous operation. Without them one would run into considerable grief.

With the privilege of buying more instruments, I would choose as follows:

1. If burning gaseous or liquid fuels, proper meters. If burning coal or solid fuels, I would use other instruments to check my combustion, using the car load lots for plant efficiency calculations.

2. Steam flow meters, of modern electrical type. These would give me the output of the boilers.

3. Feed water temperature recorder, with an indicating thermometer as a check. This is usually an inexpensive outfit and gives a very good return on the investment.

4. CO_2 recorders of the most modern type, preferably electrical, to serve as guides to my combustion. Together with these, I would like a portable Orsat gas analysis outfit to check these and to determine possible incomplete combustion.

5. Stack temperature recording thermometers, with

a portable pyrometer to check. These are excellent guides to baffle wall conditions and stack losses.

6. Air and draft gages, of the pointer type, although if the above instruments give indications of good operation, these gages serve as auxiliary instruments. At this point, I would prefer equipment for analyzing the ashes for combustible.

It goes without saying that automatic damper and feed water regulators are essential, particularly the latter. From an operating standpoint, I would place these ahead of any instruments.

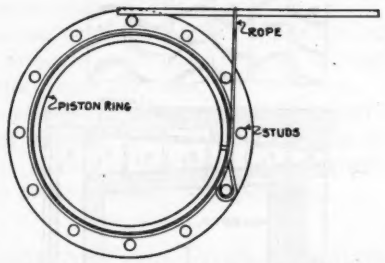
One point that I would like to bring out is the value of the proper attention to the information that these instruments give. I have seen many plants where scant attention is paid to the charts after they are changed, thus nullifying a great percentage of the dividends that these instruments pay, also the necessity of 100 per cent maintenance of the instruments with periodic checking. An inaccurate instrument is worse than none.

Dayton, O. C. W. STEVENS.

Replacing Piston Rings

PISTON RINGS may be entered into a cylinder much more easily by the following method than by either of the methods described in the April 1 and 15 issues.

When using bull ring or solid head pistons, the ring is snapped into its groove on the piston head. The piston is then pushed into cylinder until ring touches cylinder head lightly. Having tied a loop in one end of strong but light rope similar to window sash rope,



ROPE AND LEVER COMPRESS PISTON RING EASILY AND UNIFORMLY, PERMITTING PISTON TO BE PUSHED INTO CYLINDER WITHOUT TROUBLE

the loop is placed on one of the stud bolts and the rope entirely encircled around the ring, the rope being close to the cylinder. If the rings are small they may be easily compressed with one hand while the piston is pushed into the cylinder with the other, but in larger sizes a stick may be used as a lever to pull the rope taut around the piston ring to compress it.

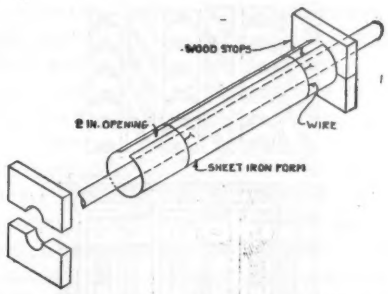
Fullerton, Ky. JOHN W. LOZIER.

Repairing Cracked Water Pipes with Cement

IN AN EMERGENCY, I have repaired breaks in water pipes with cement as shown in the accompanying illustration.

Cut a strip of sheet metal to such dimensions as will permit it to surround the pipe and be about two to three times the length of the break. Allow sufficient width to make a cylinder two inches larger in diameter than the outside diameter of the pipe. Then cut out four pieces of thin board with a half circle to fit over the pipe and block the ends of the cylinder. Bend the sheet metal around the pipe, leaving a 2-in. opening at the top and tie with wire. It can be centered with bent strips of metal inside, with small wood blocks, or with washers slipped over the shaft and located at each end of the sheet metal cylinder. Place the wood blocks abutting the ends and tie in place with wire or nails. Mix a small quantity of cement and fill up the cylinder and allow it to set until the cement is hard. The pipe is then ready for service.

This is suggested as a temporary repair but such a repair, if properly made, will stand a surprising amount of pressure and may be left indefinitely. Similar repairs have been made on fittings, outdoor pumps, etc.,



CEMENT COLLAR PREVENTS WATER LEAKAGE

and have given good service pending more permanent repair that could not be made at the time without interrupting the service.

Syracuse, N. Y. H. L. WHEELER.

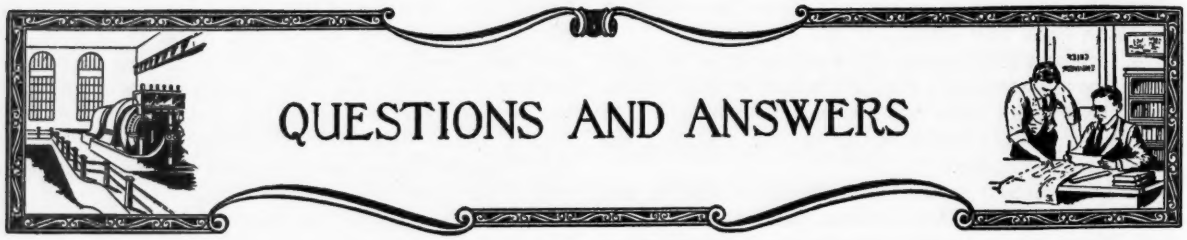
Altering Power Plant Piping

WHEN MAKING additions or changes in water and steam lines it is a common thing, where there are no flange couplings, to break a cast-iron fitting on some part of the line that is to be altered, instead of using pipe cutters on the pipe. It may be difficult to use cutters for lack of space or other reason, and it is always easy to break a fitting and use a right and left fitting to connect up the last joint. I know of more than one instance where such a job carelessly done has resulted in great amount of damage.

When a fitting is thus broken, too much care can not be used in seeing that no piece of the broken fitting falls inside the pipe line and is left there. This is more likely to happen unnoticed if the line is vertical. I know of a case where a piece of broken fitting ultimately found its way into a steam engine and was the direct cause of damage amounting to over $100.

Toronto, Canada. JAMES E. NOBLE.

TWO DISTINCT types of lubricating oil are made from petroleum and they differ fully as much in their characteristics as do anthracite and bituminous coal. In brief, it can be said that the paraffine base oil is mainly composed of hydro-carbon, with relatively high boiling point, low specific gravity and low viscosity. A naphthene base oil is composed of hydro-carbon, with relatively low boiling point, high specific gravity and high viscosity.



QUESTIONS AND ANSWERS

Steam Turbine Blading

KINDLY let me know the following:

1. Why do reaction turbines have such small radial clearance and such large axial clearance while impulse turbines have just the opposite conditions?

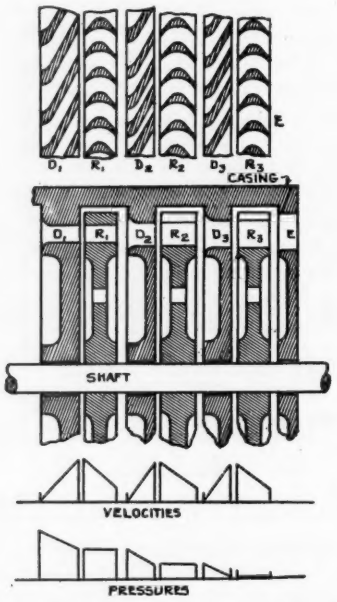


FIG. 1. CROSS-SECTIONS SHOWING RELATIONS BETWEEN MOVING AND STATIONARY BLADES AND THE CORRESPONDING VELOCITY AND PRESSURE CHANGES FOR A COMPOUND IMPULSE TURBINE OF THE RATEAU TYPE

2. Why don't they put diaphragms between stationary and moving blades on reaction turbines as they do on impulse turbines?

A. In impulse turbines there is small tendency to radial leakage, as there is no drop in pressure between the two sides of the blades, therefore, radial blade clearances in impulse turbines can be of ample dimensions.

In reaction turbines, on the other hand, it is necessary to make radial clearances as small as is mechanically possible, because in these turbines the steam expands in the moving as well as in the stationary blades, therefore a drop in pressure exists between the two sides of every row of blades. This drop in pressure causes a continuous flow of steam around the edges of the blades which is large or small according to the size of the radial clearances. The clearance between the stationary blades fixed to the casing and the surface of the rotor is, of course, just as important as that between the moving blades and the casing.

Axial clearances with respect to impulse and reaction turbines present conditions just opposite from those for radial clearances. In reaction turbines, axial clearance is not an important factor in design. Until recently, however, it was considered very important in the design of impulse turbines to make the axial clearance between the moving blades and nozzles or stationary blades as small as possible. Some of the early impulse turbines were unfortunately built with such very small axial clearances that the least vibration in the shaft would cause striking of the moving blades against the nozzles. Subsequent experience has shown that the axial clearances may be made as large as 0.20 in. without appreciable loss. This is practically as large as is allowed in reaction turbines, in which the range is from 0.20 in. to 0.10 in., depending upon the size of the turbine.

2. Diaphragms are placed between pressure stages in impulse turbines in order to prevent steam leakage

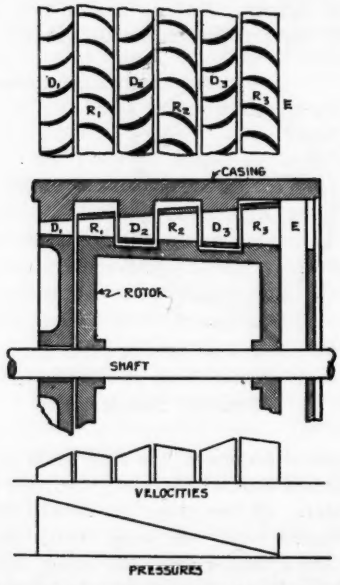


FIG. 2. SIMILAR RELATIONSHIPS FOR A COMPOUND REACTION TURBINE OF THE PARSONS TYPE

from one pressure stage to the next succeeding one, due to the decrease in pressure as the steam approaches the exhaust end of the turbine. The drop in pressure between stages in the impulse turbine is shown in Fig. 1.

In the reaction type, the steam flows through a fixed ring of directing blades, as shown in D, Fig. 2, onto a revolving ring of similar blades, R, and so on until the steam is finally exhausted at E. During this passage the pressure is gradually reduced and the need of diaphragms with shaft packing is not imperative.

The diaphragms used in impulse turbines are sta-

tionary. They are fitted into the casing, the joints formed being steam tight. To prevent steam leakage around the shaft from one pressure stage to the next, each diaphragm is fitted at its central hole through which the shaft passes, with a composition bushing having several knife edge projections against the shaft. The clearance between the knife edges and the shaft is extremely small. This bushing is in effect a small labyrinth packing gland and is held in place by a forged steel ring bolted to the diaphragm, as shown in pressure diagram Fig. 2. The corresponding velocity diagrams are also illustrated in Figs. 1 and 2.

Discharging High Pressure Steam into Brick Stacks

WHAT WOULD BE the effect of steam vent exhausting into a brick stack at 120 lb. pressure? Would this decrease the life of the stack? The steam in question is exhaust from kitchen and laundry in a hotel and the actual pressure at the exhaust is probably somewhat less than 120 lb. F. K.

A. We take it that a considerable amount of steam is exhausted from the sources mentioned. Under these circumstances, we believe the exhausting of high-pressure steam into brick stacks to be poor practice. Some municipalities have regulations restricting such practice. If high-pressure steam is to be exhausted in large quantities into a brick stack, it should first be passed through a reducing valve. Discharge at high pressure may have a scoring effect upon the stack as well as one that will weaken its structure, if not destroy it.

Depending upon the location of the discharging nozzle, high pressure steam may have an impinging action which would score the sides.

If the amount of steam exhausted is very small and the stream directed upward along the axis of the stack and if the volume of the stack is comparatively large, no serious trouble should be experienced.

Effects of Low Power Factors on Alternators in Parallel

ON PAGE 208 of the February 1 issue, the question arises as to the effects of leading and lagging power factors of alternating current generators operating in parallel, and whether there is a possibility of the generator dropping out as a result of these unbalanced conditions.

Theoretically, this is possible, but practically, it is very improbable, especially in this age of scientific research and advanced design of alternators. Theoretically, if the current were to lead or lag the voltage component to such an extent as to be displaced 180 deg. out of phase, or directly opposite each other, the resultant would be a short circuit, and the unit if equipped with protective devices would automatically be cut off the system.

Practically, however, this never occurs, due to design features of present-day alternators, especially on a system having a large distributed capacity, both in generator capacity and line reactance. The nearest that could ever approach these conditions, from a practical standpoint, would be a case of severe hunting, where two high-speed prime movers, both governed, not mechanically coupled, were each driving an alternator, and these alternators operating in parallel each being loaded to at least 85 per cent of its full capacity. Considering that no other alternators are also operating in parallel with these two, the following could take place: Should one of these governors fail to operate properly, the tendency would be for that unit to increase or decrease its speed. The other governor would function in the opposite direction with a tendency to bring the speed back to normal. The result would be a swinging variation of speed, mechanically, and a surging of current, voltage, and load values, electrically, between the two units, due to these speed changes, and by these facts, a like variation of power factor would result, but not to the extent of complete phase opposition. Present day designs call for dampers on the field coil system, high reactance values of the armature conductors and protective devices on the mechanical end, these make such possibilities, as complete phase displacement, out of the question as concerns hunting.

The only harmful result that may be expected from a very abnormal power factor, either lagging or leading, would be a current overload beyond the rated capacity of the alternator, as specified on the nameplate by the manufacturer and then, if of short duration, no harm generally results unless there is a weak spot such as a breakdown in insulation. This abnormal increase in wattless current, in the form of cross currents is caused by the difference in phase displacement and the difference in potential levels between the two units, in turn caused by the differences in speed. This wattless kv.a. may be represented vectorially by a current and voltage triangle with the hypotenuse representing the wattless component and the angle representing the phase displacement or power factor.

Winooski, Vt. JOHN B. MANSFIELD.

Proper Selection of Packing Avoids Trouble

WE ARE USING 2-in. cup leather packing with flax packing around the hydraulic plungers of our elevators and hydraulic accumulator. These are all working under 1100 lb. per sq. in. pressure. The elevators are operated with balanced hydraulic valves. The packing gives us a great deal of trouble, due to the flax packing around the plungers wearing off in small particles and lodging in the ports of the balanced valves. These particles of flax wear grooves in the leathers.

It is the writer's idea to place strainers ahead of the balanced valves, thereby preventing the flax from entering them. Where could we obtain strainers that would stand this pressure of 1100 lb. per sq. in.? J. A.

A. We believe that you would overcome your difficulty best by using a plastic packing instead of a flax packing. Plastic packing accommodates itself to worn parts and the use of such packing would avoid the breaking off of particles such as you experience in the use of the flax packing, therefore there should be no need for the use of a strainer.

If a strainer were used, there would be no need to have an extra strong strainer, so long as the holes were open, as the pressure would be rapidly equalized; but if a strainer were used and you continued to use your flax packing, we believe that it would be rapidly clogged up, causing you considerable trouble.

EDITORIAL COMMENT

National Power Day

From one end of the country to the other the public meets the sign "Keep Out" at doors and gates of power plants, both industrial and central station. Good and sufficient reasons exist for the keep-out policy which has been so generally established by the owners and managers of power plants. In the first place, curious people are likely to do damage to machinery and, in the second place, through their unfamiliarity with power plant equipment, they are subject to dangers which sometimes result in serious injury or death.

Nevertheless certain distinct benefits can be derived by power plant owners in opening their doors to users of electricity and explaining the equipment and its principles of operation to those sufficiently interested in the plant to visit it.

To maintain agreeable public relations is one of the most difficult problems of the public utility and it is quite generally recognized that most of the unpleasant encounters with the general public are due to ignorance or unfamiliarity with the operation of public utilities. Rates and service are two common points of contention and both of these can be discussed more intelligently when the public has a general knowledge of plant equipment and difficulties encountered in operation.

In the industrial plant, employes using power should be taught its value and this can best be done by a visit to the power plant where the fuel is being burned, steam generated, electricity produced and controlled. The machinery is impressive and its initial and maintenance costs will be better understood as a result of such a visit. In this way the superintendents of the various departments can point out the justification for many rules which they require their operators to follow.

At such a time as during a visit to a power plant, a man's mind is receptive to demonstrations of the applications of electric power in the household and in industrial work. In this, appliance manufacturers could cooperate. Economy, convenience, and the more healthful conditions brought about by the use of electric power in the home and factory could well be pointed out at such a time, if not at the plant where space and other conveniences are not always available, at some electric shop where demonstrating platforms, tables and show windows can be used.

To keep open house in the power plant every day in the year is impracticable and would lead to unwarranted expense, but it would seem that, if one day during the year were set aside as visitors' day, much good could be accomplished. Greatest success and widest interest would be had if all the power plants of the country observed the same day. In addition to conducting parties through the plants where visitors would see and learn the function of the various principal pieces of equipment, radio programs dealing with power problems of national interest could be arranged, the entire day being devoted to enlightening the public at large on the economical generation and use of power and its importance to our home and industrial life.

With proper publicity, we believe sufficient public interest would be aroused to make a National Power Day well worth the effort to arrange.

Changing Positions for Success

No man is indispensable. An employe's value to any concern is merely his replacement value; an employer's value to the individual varies with the law of supply and demand in the labor mart.

Labor has two extremes, the man who sits content with himself, his position and his pay—and the "floater." Between these two extremes lie power, ambition, success and all the other fine attributes of attainment. Regardless of our personal position we cannot condemn either the extremes or what lies between. If a man be content to get ahead simply by seniority, he avoids the cares and burdens of success. He misses responsibility of any magnitude, is content to go about his routine work and to cease his labors as suddenly as an East India elephant who hears a dinner bell. Routine work is essential to industry and someone must do it.

This type of man has one sad moment in life, when some younger engineer replaces him and he steps down reluctantly but with a sigh of relief, to continue his services in a capacity more honorary in nature than essential to production.

Again, we are prone to condemn the "floater" yet it is he who harvests the western wheat crop, who helps construct our large power plants and, in general, fills in the labor gaps as they occur in our present system of output.

After all, it is the man in between that concerns us most. Any man fired by ambition is bound to succeed, if he has the good judgment to keep success from going to his head. The intelligence to grasp opportunity by the forelock will determine his progress on the road to success.

Adversity tempers the man; it cracks the weak to weed him out, case-hardens the "Mexican athlete" that his thin veneer of knowledge may give him sufficient protection to be adjudged successful but, for the man possessed of the necessary carbon, it penetrates to temper him with additional strength against the strains, stresses, shearing and torsion of daily conditions.

Ambition is a slave driver, a Simon Legree whose lash cuts and sears and burns. It begets envy, it breeds jealousy; it demands strength of mind and body in pursuit of the rainbow of success that is always off the horizon, sometimes almost within our reach, sometimes fading into greater distance at our approach.

Throw egotism, envy, jealousy overboard at the first sign of their appearance. They are loose ballast that will sink any ship.

Success demands sacrifice, accepts tribute and is possible only through opportunity and perseverance. We who keep our "noses to the grindstone" know of perseverance, but what of opportunity?

Opportunity is the privilege of all persons having a definite goal in mind and whose progress to that goal is based on a foundation of experience, consideration of others and application to the task in hand. Many firms, because of size, nature of product or other limitations can provide only limited opportunity for large success within their own folds, but every firm, regardless of size, gives opportunity for a proper foundation for ultimate success. When employed by a plant that has natural restrictions, it is well to take stock of your abilities, reach the limit with that firm, and only then seek a larger area for intellectual grazing.

Whether or not opportunity will be grasped at the opportune time can be decided only by future events. If your work has merited reward, it will be forthcoming in order to retain your services and, if the reward offered is aside from your ambition, it may be hard to pass up the immediate reward for an uncertain future but, if bound for success, a temporary reward of any nature may be a deterring factor in reaching it.

Opportunity knocks but, like time and tide, she waits for no one. She may return and it is then that a man must take inventory of himself to determine how far he wills to go, how far he can go and whether he is going. One must determine his own capabilities and desires. Big fish can grow in little ponds and there is room for lots of fish in big ponds. Industry provides all sizes with open passage to the ambitious.

To be successful, pick your field in the arts and stick to it blindly and devotedly. Set a mark in salary, position or honor,—then work. Advance the goal, if necessary, and work the harder to attain it.

It will require decisions as to employers but remember, a guess has a fifty-fifty chance of being right and, when a guess is influenced by your own and better counsel, it becomes sound judgment.

Straightforwardness is an essential element in the make-up of any man attaining success. Give your employer every opportunity to see your virtues and, if he fails to see them, it is then time to look for other positions but do not seek them merely to force his hand; it simply cannot be done, though it is possible that he has not thoroughly appreciated your services until the time comes to replace you, in which case it becomes necessary to accord him consideration, if for no other reason than courtesy. It is well to remember as employer and employe that whatever is done should be done in such a manner as to cause no embarrassment in future years.

Cultivate "squareness." The greatest religion on earth today is embodied in the Golden Rule. The worst employer is not as bad as he is painted and the best is not perfect. Don't let his good points deflect your course nor his bad points deter your ambition, even though a pat on the shoulder from one employer may seem nearly the equivalent of a salary increase from another.

Direct requests for salary increase should be avoided; a good buyer knows wool from shoddy and shoddy may answer his requirements. If so, it will be as economically impossible for him to purchase wool as for you to supply shoddy. Furthermore, a request brings about a direct collision. Granting it means little or nothing but refusal leaves the request answered in a manner apparent to any one and further efforts should be directed toward a field of greater possible growth.

Selection of employers should receive the same attention that the employer gives to his employment bureau. The satisfaction of working under a capable and considerate employer makes life worth while as we travel toward our goal. It often precludes the necessity for changes and, to say the least, all changes, though they have a definite value in reaching our final goal, should be as few as is consistent with enjoyment of work and a record worthy of any employer's attention.

European Supremacy

"A prophet is not without honor save in his own country" might well be, with the permission of the clergy, of course, extended to include engineers and scientists. A few generations ago, before the art of clever conversation had declined, the metaphor would have been acceptable but today, when conversation is limited largely to three or four-word, ready-made, snappy come-backs and life is dominated by the drab materialism of the one hundred per center, we are not looking for subtleties and hidden meanings.

It is but human nature to overlook the immediate details of progress in our own country and admire accomplishments in Europe just as we miss the grandeur of the mountain we climb to view the beauties of another.

We read with wonder of the accomplishment of foreigners in the field of research and engineering. Of course, there is a certain confidence and tolerant pride of our countryman. Just as we know John Paul Jones would have captured or sunk the entire English fleet without difficulty if they had been indiscreet enough to appear, or that Washington could have whipped the British single-handed if he had not been fortunate enough to have a few friends to help, so we know that our scientists and engineers are the best in the world, but the bouquets and applause go to the foreigners who, viewed from a distance, can hide their defects and feature virtues bolstered up by a few imposing degrees and the popular conception of superior educational institutions.

It is with some hesitation, therefore, that we brave public opinion to buckle on the armor of our trusty knight and send him forth with the challenge formulated by Mr. Alden at the A. S. M. E. Kansas City meeting that "there is not a single station in Europe that is doing better than 20,000 B.t.u. per kw-hr. There are only two in England that are hitting around 19,000; . . . here we have many, many stations that are doing better than 17,000 B.t.u. We have the results of one station that has generated power for less than 13,000 B.t.u. per kw-hr. for some three or four months."

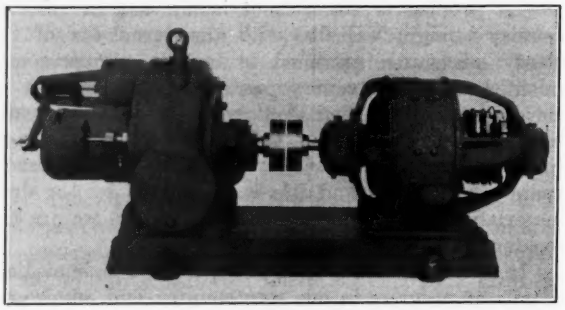
The power plant engineer may not be making the world any safer for democracy, but he certainly is doing a better job than his European brother in making it a pleasanter place in which to live.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Small High Speed Turbine

DEVELOPED primarily for auxiliary drives in modern high pressure steam plants, a new turbine is being offered by the Terry Steam Turbine Co., Hartford, Conn.

This machine is ordinarily used for horsepowers of 30 or under and for speeds of from 2000 to 6000 r.p.m.,



THIS TURBINE WAS DESIGNED PRIMARILY TO DRIVE SMALL AUXILIARIES IN HIGH PRESSURE PLANTS

for steam pressures as high as 400 lb. and back pressures up to 30 lb. The wheel is a standard Terry single feed design and the bearings are of the deep groove ball type.

Oil is automatically fed to the bearings and any excess is thrown out at the top and returned to the reservoir. The governor is of the flyball type completely enclosed and the governor valve body, to secure simplicity, is cast integral with the casting and provided with a cylindrical strainer. The governor valve seats, however, are separate from the body and are removable. As on other Terry machines, the jets are provided with hand valves so that they can be shut off for partial load conditions or opened up for low steam.

Condenser Tube Cleaner Has Flexible Steel Scrapers

FOR THE PURPOSE of keeping the tubes of surface condensers free from scale, the Wm. B. Pierce Co. of Buffalo is marketing the plug type cleaner shown in the accompanying illustration. These devices, known as Conco cleaners, are scrapers which are passed or shot through the condenser tubes under water pressure. They are so constructed that part of the water passing the scrapers washes away all loosened deposits and prevents clogging of the cleaners.

As may be seen from the illustration, the Conco cleaner is fitted with ten independent steel scrapers which are held tightly against the tubes by spring tension. These provide the flexibility necessary to make them conform closely to the surface of the tubes while yet exerting sufficient scraping action to accomplish thorough cleaning.

While these cleaners may be forced through the tubes by various means, the Wm. B. Pierce Co. is put-

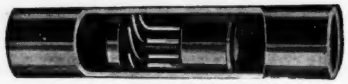


FIG. 1. CONCO CONDENSER TUBE CLEANER

ting out the Conco gun shown in Fig. 2 which is made especially for shooting the cleaners through under water pressure. It is particularly desirable in cleaning large condensers when the heads are not lifted, also in cleaning one-inch tubes that are scaly, making high pressures necessary. With this gun it is a simple matter to insert

FIG. 2. THE CONCO GUN FOR SHOOTING THE CONCO CLEANERS THROUGH CONDENSER TUBES

the cleaners and shoot them through with a stream of water under pressure. For smaller condensers or where sufficient water pressure is not available, the cleaners can be put through the tubes at the end of a rod with satisfactory results.

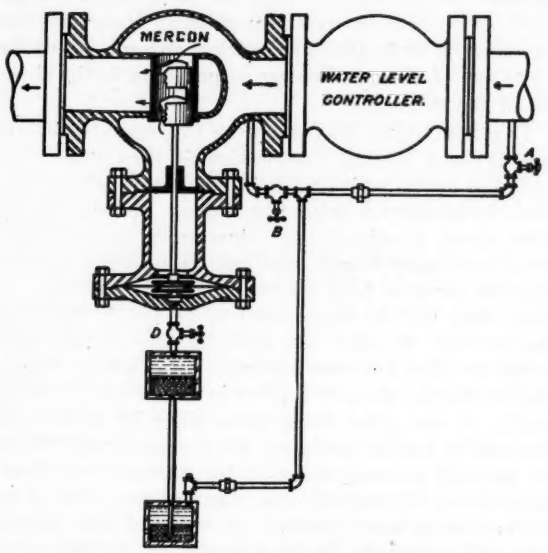
Differential Regulator Maintains Constant Pressure Drop

DESIGNED to maintain a constant pressure drop across the boiler water level controller valve at all pressures, ratings and flow, the new back pressure type Mercon BXP has been developed by the Mercon Regulator Co., Chicago, Ill. The new regulator holds the outlet pressure at a set point under the inlet pressure and is installed on the boiler side of the water level controller.

Should the control piping be ruptured, the valve opens wide so as not to restrict the flow and, should there be any minor leakage between the column and diaphragm chamber, the water necessary for replacing the leakage simply bubbles up through the mercury in the column and does not effect the height of the latter or change the pressure exerted.

Operation of the new valve is apparent from the

illustration. The inlet pressure to the level controller is transmitted through a ¼-in. pressure connection to the bottom mercury pot. Assume this pressure to be 400 lb. A starting head of 40 in. of mercury or 20 lb. in the column is subtracted from the 400 lb., making the pressure in the top mercury pot on the under side of the diaphragm 380 lb. As long as the pressure above the diaphragm equals this pressure of 380 lb. the diaphragm and the Mercon valve remain in a fixed position.



THE NEW BACK PRESSURE REGULATOR IS INSTALLED ON THE BOILER SIDE OF THE WATER LEVEL CONTROLLER

When the pressure on either side of the diaphragm fluctuates, however, the diaphragm and valve move accordingly and seek a position which will again hold the latter in balance. This operates automatically to keep the discharge pressure of the level controller the fixed amount of 20 lb. less than the inlet pressure.

A. I. E. E. Holds Summer Convention in Detroit, June 20-24

WELL-BALANCED LISTS of papers and a full program of attractive recreational features mark the coming Summer Convention of the American Institute of Electrical Engineers, which will be held at the Book-Cadillac Hotel, Detroit, Mich., from June 20 to 24. For the technical sessions, many papers on practical operating subjects have been chosen as well as some of the latest scientific contributions. All branches of electrical engineering will be covered by the reports of the Technical Committees.

For the entertainment of the visitors, golf and tennis tournaments are planned, together with boat trips, dancing, receptions, teas and sports for the women and inspection trips to Fordson plant, Trenton Channel and other plants of interest. Arrangements may be made for a lake trip after the convention.

Alex Dow is chairman of the general convention committee, with G. B. McCabe as Vice-Chairman. G. H. Roosevelt is chairman of the entertainment committee, J. W. Bishop of the hotel committee, and F. H. Riddle of the registration committee.

Monday, June 20, the first day of the convention, is to be devoted to registration and section conferences. On Tuesday morning the convention will be opened and at 10:30 a. m. a technical session will be held. Here will be presented papers on Holtwood Steam Plant by F. A. Allner, Auxiliary Power Supply for Richmond by J. W. Anderson, Recent Investigations of Transmission-Line Operation by J. G. Hemstreet and Use of High Frequency Currents for Control by C. A. Boddie. In the afternoon, golf and tennis tournaments are scheduled and in the evening is a lecture on The Physical Nature of the Electric Arc by Dr. D. T. Compton, followed by the president's reception and dance.

Wednesday, June 22, will be devoted to the reports of the technical committees, with a trip to Trenton Channel in the afternoon and a dinner in the evening.

On Thursday, June 23, another technical session is scheduled with papers on ocean cable telegraphy, electrical reproduction of sound, high-voltage multiple conductor joints and others.

Morning and afternoon technical sessions are to be held on Friday, June 24. Papers will be presented in the morning covering corona loss, insulating materials and mercury arc rectifiers. The afternoon session will be of particular interest to railway engineers as it will be devoted almost entirely to papers on catenary suspension.

Chicago Power Show and Conference Announced for 1928

ANNOUNCEMENT IS MADE of the Third Midwestern Engineering and Power Exposition to be held in the Coliseum Building, Chicago, February 14 to 18 inclusive, 1928. Several noteworthy changes have been made in the building which will be of advantage to both exhibitors and visitors and the new layout of the booths is expected to eliminate some of the disadvantages encountered last year. The new floor plan takes advantage of the enormous size of the building, which is nearly 500 ft. long and 175 ft. wide. The north and south hall layout plan has been re-arranged to give a vista to the aisles showing the great depth of the building and the consequent large number of exhibits which will be available. It is now planned that the exposition will run for five days and the hours will be made to suit the convenience of the exhibitors and visitors.

Concurrently with the power exposition the Third Midwest Power Conference will be held from February 14 to 17. Further data regarding programs and hours of meetings will be announced later.

News Notes

LINCOLN ELECTRIC CO., Cleveland, O., announces a new line of all steel, ball-bearing, polyphase induction motors in sizes from 1 to 100 hp. Because of the use of steel, less weight of frame, increased ventilation and increase in overload capacity are claimed for this new design.

GENERAL AIR FILTERS CORPORATION has appointed the Dingle-Clark Co., 311 Ross St., Pittsburgh, as its

representatives to handle air filters, air washers and spray pond equipment.

WILLIAM B. SENSEMAN has been appointed Pacific Coast district manager for Combustion Engineering Corp., Raymond Bros. Impact Pulverizer Co., Ladd Water Tube Boiler Co. and Heine Boiler Co., all subsidiaries of International Combustion Engineering Corp. Mr. Senseman has been associated with Raymond Bros. Impact Pulverizer Co. for the past 15 yr. and, since 1917, has represented that organization on the Pacific Coast. The new consolidated offices are located in the Subway Terminal Building, 417 South Hill St., Los Angeles, California.

TWO REELS of moving picture films have recently been completed by the Gas Products Association with headquarters at 140 So. Dearborn St., Chicago, Ill., to show the correct methods of welding and cutting by means of oxy-acetylene. The film shows the welding and cutting processes as they are universally used for repairs to broken metal parts, for cutting heavy risers from steel castings, for repairing larger sections of cast iron in connection with heavy presses and welding extremely light parts, such as plates for radio condensers, for repairs for the farm and in the welding shop, the welding and cutting of structural steel, the welding of pipe lines for high-pressure gas and also in connection with buildings. The Association states that a limited number of prints of these films are available to organizations to show them to audiences by making application to the Association's secretary.

THE PENNSYLVANIA RAILROAD, Philadelphia, Pa., has begun the construction of its proposed new produce terminal on a 40-acre tract of land bounded by Delaware, Vandalia, Packer and Pattison Avenues, to include a large cold storage and refrigerating unit. The latter will be eight-story, 100 by 250 ft., with remainder of the building 110 by 800 ft., over all, to be two-story for the present, with foundations to provide for an additional six stories at a later date, the entire structure to be used as a cold storage and refrigerating plant unit. The group will consist of two other buildings, each two-story, 100 by 800 ft., equipped with mechanical handling and conveying machinery, etc. The entire project will represent an investment of close to $15,000,000.

ANNOUNCEMENT IS MADE that four new generating units are to be added to the Keokuk power plant by the Mississippi River Power Co. adding 40,000 kw. to the capacity of the station. It is expected that two of the new machines will be ready for operation March 1, 1929.

CONSTRUCTION WORK on the new brick and concrete $450,000 steam power plant being erected by the Otter Tail Power Co. at Wahpeton, N. D., is progressing rapidly and it is expected to be ready for service about October 1st of this year.

Steam at 300 lb., 175 deg. superheat from two 750-hp. Badenhausen boilers, each fired by two 8 by 16 Harrington chain grate stokers, will be used for power generation in one 3000-kv.a., 2300-v., 3-phase, 60-cycle General Electric turbo-generator.

RE-ENTRY INTO the California hydroelectric field of Yosemite Power Company on a large scale is forecast with the application to the Federal Power Commission at Washington for license to develop its Tuolumne River properties. The development will, it is understood, involve an investment of upward of $6,000,000 and the setting up of power machinery with an installed capacity of a probable ultimate 51,000 hp. Public financing is anticipated in connection with the project when favorable consideration is given at Washington. The company already has State sanction. The application of the Federal Power Commission contemplates the construction of two reservoirs of 65,000 acre feet capacity, one near Carl Inn and the other not far from Groveland. Three power houses and transmission lines are also proposed. Manufacture of electrical current for wholesale to one of the large power corporations is the objective of the development.

THE LEXINGTON WATER POWER CO., operated by the General Gas & Electric Corporation, 50 Pine Street, New York, has begun active work in connection with a proposed hydroelectric generating plant on the Saluda River, about 10 miles from Columbia, S. C., at a place known as Dreher Shoals, and has taken over a tract of about 50 acres of land for the initial development. A power dam will be constructed to be 188 ft. high and close to 8000 ft. long; an artificial lake will be built behind the dam for water storage, to be about 30 miles long, averaging close to 3 miles in width for the entire length, at one point being more than 10 miles wide. The station will be equipped for a capacity of 200,000 hp., and will be connected with the system of the Broad River Power Co., an affiliated organization, with an extensive transmission system. A railroad line will be built to be used for hauling machinery to the power site. The entire project will represent an investment of close to $20,000,000. W. S. Barstow is president of the parent company.

THE CAROLINA POWER & LIGHT CO., Raleigh, N. C., has work under way on two new hydro-electric generating plants, estimated to cost close to $21,000,000. The first station is to be located on the Yadkin River, near Norwood, N. C.; it will be equipped for a capacity of 62,000 kw. and is estimated to cost about $9,000,000, with transmission system. The second plant, to be known as the Waterville Station, will be situated on the Big Pigeon River, near the North Carolina-Tennessee state lines; it will have an initial output of 66,000 kw., and is expected to cost close to $12,000,000. At a later date the last noted station will be enlarged to 100,000 kw. The company is carrying out a transmission extension program in connection with these new power units including a connection with the system of the Appalachian Electric Power Co., with 132,000-v. single circuit line to a point near the North Carolina-Virginia state line. A connection will be made, also, with the system of the Tennessee Public Service Co., at a point near Waterville, Tenn., as well as with Southern Power Co., at Greenville, S. C., and with the Virginia Electric Power Co., at Battleboro, N. C.

ACCORDING TO DATA collected at the biennial census of manufactures taken in 1926, as announced by the Department of Commerce, the production of engines and other primary power machines in the United States in 1925 was as follows: Reciprocating steam engines, 2338, having a combined rated capacity of 208,311 hp., valued at $4,995,392; steam turbines, 2475, rated hp. 1,111,888, value $9,125,801; steam traction engines (other than

locomotives), 101, rated hp. 4127, value $257,623; Diesel engines, 4101, rated hp. 409,390, value $21,979,617; other internal-combustion engines, 543,764, rated hp. 8,353,236, value $92,884,161; tractors, 168,299, rated hp. 3,765,023, value $103,900,262; tractor trucks (semi-tractors), 799, value $1,258,808; water turbines and water wheels, 475, value $5,338,066. In addition, engines and turbines to the value of $23,558,168 were reported by manufacturers who failed to comply with the Census Bureau's request for data as to number and horsepower. The total, $263,297,898, represents an increase of 18.1 per cent as compared with $222,963,808, the corresponding total for 1923. Of the total value of the 1925 output, $222,390,553 was reported by establishments whose principal products were engines and other primary power machines, and $40,907,345 by establishments which were engaged primarily in other industries but which made engines and other primary power machines as secondary products.

THE CITY COUNCIL, New Ulm, Minn., has rejected an offer by the Interstate Power Co. for the purchase of the local electric light, power and heating plant. The plant will be extended and improved for increased capacity. A new twin Nordberg engine generator unit of 1250-kv.a. capacity with the usual auxiliaries will be installed in the near future.

EXTENSIVE ADDITIONS to the Oakland, California, steam electric plant of the Pacific Gas and Electric Co., involving an expenditure of $2,750,000 have been approved. According to an announcement made by L. H. Newbert, division manager of the company, the work is to be started immediately. It will include the removal of a 12,000-hp. turbine and eight 750-hp. boilers to be replaced with two 3400-hp. boilers and a 47,000-hp. high pressure steam electric turbine with necessary auxiliaries. The turbine to be removed was installed in 1908, and was the first steam electric turbine to be installed in the Pacific Gas and Electric Co.'s system.

Electric energy is now delivered to the East Bay cities over hydroelectric transmission lines through three primary channels, i. e., through lines entering at Crockett, Antioch and Newark. These lines are interconnected with 28 hydro-electric plants in the Sierras and the big steam plants at Oakland. The capacity of the steam electric or stand-by plant at Oakland through this new installation will be doubled, with an installed capacity of 71,500 hp.

Books and Catalogs

HYDRO-ELECTRIC HANDBOOK by Wm. P. Creager and Joel D. Justin, with the assistance of nine contributors; flexible binding, 6 by 9½ in.; 897 pages, 494 illustrations; New York City, $8.00 net.

This book was written to provide for the hydro-electric plant engineer a compendium of all the authentic hydraulic information now available. The major part of the work is by Wm. P. Creager, vice-president and chief engineer of The Power Corp. of New York, and Joel T. Justin, hydraulic engineer of the U. G. I. Contracting Co. These names, together with the list of the other contributors to the book are, it seems to us, sufficient guarantee of the authoritative tone of the work.

The first eight chapters by Mr. Creager present a concise but extremely practical discussion of the subjects of rainfall, evaporation, factors affecting runoff, estimation of stream flow, discussion of capacity of the development, output capacity and flow demand and analysis of the factors that must be considered in determining storage and power available. This is followed by two chapters by Mr. Creager, one on the fundamental principles of hydraulics and the next on the general considerations in the design of a hydro-electric project, placing particular emphasis on the theories of economical design.

Then follow chapters by both Mr. Creager and Mr. Justin on the details of design and construction of various types of dams, together with head water control, locks, conduit intakes, canals, flumes and various types of steel and wood stave pipe. A discussion of the theory of water hammer is presented by Mr. Creager and Eugene E. Halmos, who it will be remembered, translated Allievi's Theory of Water Hammer. This discussion leads naturally to the treatment of the design of surge tanks.

Design and construction of the power house superstructure are taken up by Joseph H. Gandolfo, followed immediately by a most exhaustive treatment of hydraulic turbines by Wm. M. White and of electrical design by Raymond A. Hopkins.

The chapters on electrical design by Mr. Hopkins are extremely detailed and present the latest available information concerning generating equipment, switching equipment and transmission line equipment.

The book is brought to a close by a chapter on river gaging by Nathan C. Grover and John C. Hoyt and a chapter on operation of hydro-electric properties by Wm. W. Tefft.

Although several years have been spent in the preparation of this Handbook, considerable care was exercised during the last few months of its preparation to check up all material and to incorporate discussion of the very latest practice. Each chapter is followed by a comprehensive bibliography. The volume has been well printed on a good grade of fairly thin paper, and is about the same size and shape as some of the other standard handbooks.

In short, we feel that Messrs. Creager and Justin have performed a distinct service to the hydro-electric field in compiling this Handbook.

"ELECTRIC POWER STATIONS," by L. W. W. Morrow, first edition, 326 pages, size 6 by 9, cloth, $4.00, New York, 1927.

An excellent book giving an up-to-date picture of the modern power station. The production, transmission and distribution of electrical energy on a large scale in an adequate and economical manner is an engineering task of the first magnitude. Each system has its specific details and problems, the solution of which depends largely upon local conditions, but there are certain fundamental engineering and economic principles that apply to all systems.

In this book, therefore, the author neither discusses the modern power station from a purely technical standpoint nor from a purely financial standpoint but strikes a path somewhere between the two views. He outlines the guiding principles which underlie the production,

transmission and distribution of power as exemplified by the best practices and opinions today. While it is shown that the basic engineering principles, civil, electrical, chemical and mechanical are the only true guides, costs and relative values, it is pointed out, are determining elements in their application.

The book presupposes a fundamental knowledge of the types of power plant transmission and distribution equipment as regards its operating principles and constructional details.

In a circular, the Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, shows how the CO_2 recorder may be used to cut fuel bills.

Botfield Refractories Co., Philadelphia, Pa., has recently issued a pamphlet describing the Adamant gun for use in facing or coating the fire exposed surfaces of new or old furnace linings with firebrick cement.

Hahn Engineering Co., Philadelphia, Pa., has recently issued a leaflet describing the Hahn octagonal sectional cast-iron storage tanks. These tanks are fitted with thawing-out steam chambers and rotating agitators.

Francke flexible couplings are described, the uses outlined and sizes and dimensions given in a 32-page catalog, Bulletin No. 37, issued by Smith & Serrell, 20 Washington Place, Newark, N. J.

Bulletin A-2300, recently issued by the Yeomans Brothers Co. of Chicago, Ill., describes form A ejectors, which are of the non-clogging type and operate without the use of any screen devices. The bulletin is well illustrated and describes the operation and details of construction of the ejectors.

Pennsylvania air compressors and vacuum pumps are described in bulletin No. 132 recently issued by the Pennsylvania Pump & Compressor Co. of Easton, Pa. This bulletin describes especially the single-stage air compressor and vacuum pumps, also class 3-AE direct synchronous motor-connected air compressors.

"Direct Steam and Oil Separators" is the title of catalog S-24 recently issued by The Direct Separator Co., Inc., Syracuse, N. Y. This catalog is a rather comprehensive treatise on the subject of the separation of water from steam and describes rather thoroughly the operation of the Direct Separator and its construction.

Under the title De Laval Pumps at Greensboro, N. C., the De Laval Steam Turbine Co. has described a pumping system in which an original capacity of 4,500,000 gal. daily was increased to an ultimate 22,000,000 gal. daily without expenditure for new buildings and with marked improvement in fuel economy, by the substitution of steam-turbine driven centrifugal pumps for Corliss and Meyer valve gear, crank and flywheel units. This leaflet will interest waterworks engineers who are faced with the necessity of increasing the capacity of old pumping stations.

The American Society of Mechanical Engineers, 29 West 39th St., New York City, is distributing a booklet giving the conditions governing the award of Lincoln Arc Welding prizes for 1927, mentioned in the April 15 issue of Power Plant Engineering. As previously stated, the Lincoln Electric Co. has placed in the custody of the Society $17,500 to be awarded in three prizes of $10,000, $5000 and $2500 for the best three papers disclosing advancement in the art of arc welding. The Society will appoint a committee of judges to pass on the papers and recommend the awards. The winners of these prizes will be selected on the basis of amount of economic saving shown by their suggestions. Full details of the rules of the competition, with data to assist entrants, are given in the booklet, which can be obtained from Calvin W. Rice, secretary of The American Society of Mechanical Engineers at the above address.

"Multi-Pointer Gages for Draft and Other Factors" is the title of a new 16-page bulletin just issued by the Bailey Meter Co., Cleveland, Ohio. This bulletin is a revision of a former edition and describes gages to indicate drafts, low pressures or pressures up to several hundred pounds. Any reasonable ranges of temperature can be indicated, as well as revolutions per minute and indicating flow units for feed water, steam, gas, air, and the like, can also be incorporated. In fact, the entire set of indicating gages and instruments of an elaborate gage board can be combined into one compact self-illuminated, Multi-Pointer gage, as described in the bulletin, with as many as 12 units. These gages may also incorporate units designed for operating signal devices and for indicating water level in storage tanks. The bulletin illustrates many interesting applications of the Multi-Pointer gages and gives details of the construction of the individual units.

The K. S. G. process for low temperature carbonization of coal is made the subject of bulletin IC-3 recently issued by the International Combustion Engineering Corp., New York City. The object of this process is to convert low grade fuels and mine waste into valuable and commercial products, to distill either caking or medium caking coal with the same installation and to obtain uniformly high grade products in large volume.

Worthington Pump & Machinery Corp., 115 Broadway, New York City, has recently issued its bulletin HO-1900 under the title of "Equipment for Power Plants." Particular attention is given in this bulletin to modern power plant practice as regards steam condensers, pumps, air compressors, Diesel engines, gas engines and oil and water meters. It also contains practical information of value to power plant and consulting engineers.

Catalog No. 100 recently issued by The New York Blower Co., 2248 Halsted St., Chicago, Ill., is a very attractive catalog describing the company's type ME fan. The catalog illustrates and describes in detail the outstanding features of these fans and the various methods in which they may be installed. There is also included in the catalog, blank specifications for convenience in ordering this equipment, as well as a rather complete set of tables giving the capacities of the various sizes manufactured.

Bacharach Industrial Instrument Co., Pittsburgh, Pa., in bulletin No. 131, describes and illustrates Bacharach manometers, giving dimensions and tabulations of prices. These manometers are of the single tube type and are furnished in upright types with ranges of a few inches of water up to 20 lb. and as inclined manometers with ranges up to 6 in. of water. The magnifying manometer magnifies the reading obtained with the mercury manometer, employing for the purpose another liquid moved by the mercury.